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RESEARCH MEMORANDUM

AERODYNAMIC CHARACTERISTICS OF TWO RECTANGULAR-PLAN-FORM, ALL-MOVABLE CONTROLS IN COMBINATION WITH A SLENDER BODY OF REVOLUTION AT MACH NUMBERS FROM 3.00 TO 6.25

By Thomas J. Wong and Hermilo R. Gloria

Ames Aeronautical Laboratory
Moffett Field, Calif.

NATIONAL ADVISORY COMMITTEE
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AERODYNAMIC CHARACTERISTICS OF TWO RECTANGULAR-PLAN-FORM, ALL-MOVABLE CONTROLS IN COMBINATION WITH A SLENDER BODY OF REVOLUTION AT MACH NUMBERS FROM 3.00 TO 6.25

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SUMMARY

Results of force and moment tests at Mach numbers from 3.00 to 6.25 on two rectangular-plan-form, all-movable controls in combination with a slender body of revolution are presented and compared with the predictions of theory. The controls had aspect ratios of 4/9 and 1 (for exposed panels joined together) and ratios of body radius to wing semispan of 0.6 and 0.4, respectively. The body had a fineness ratio of 12. The models were tested at angles of attack up to 25°, control deflection angles from -30° to +30°, and Reynolds numbers based on control chord from 0.23 million to 1.2 million, depending on test Mach number.

The results showed that lift variations with angle of attack were somewhat nonlinear for both control-body combinations tested. However, linearized wing-body interference theory when combined with experimentally determined characteristics of the body gave, for the most part, adequate predictions of lift, drag, and pitching-moment coefficients of the control-body combinations.

Control hinge moments were linear only at small angles of attack and control deflection. Hinge-moment parameters were influenced to a large extent by the shape of the airfoil section and, hence, were not well predicted by linear theory. A method which considers this effect, the slender-airfoil shock-expansion method, provided better estimates of these parameters.

INTRODUCTION

The problem of providing adequate control for missiles traveling at high supersonic speeds is aggravated by the well-known decrease in lift effectiveness of planar surfaces with increasing Mach number. Due to this decrease, it is often desirable at high supersonic speeds to employ the entire stabilizing surface for control - that is, as an all-movable control. For various reasons, these controls are generally small and, therefore, operate entirely within the disturbed flow field created by the missile body. It follows, then, that wing-body interference will usually play an important role in the aerodynamic characteristics of the body-control combinations.

At low supersonic speeds, the nature of wing-body interference is reasonably well understood. There is a large amount of experimental data available and several theories for treating the interference flows. For the case of an all-movable wing, the theoretical methods include that of Tucker (ref. 1) who treated only the lift, using linear theory with approximate boundary conditions. There is also the work of Nielsen, Kaattari, and Drake (ref. 2) which is based on a combination of linear and slender-body theory. This method provides predictions of the lift, pitching moment, and hinge moment. This result has been extended by Katzen and Pitts (ref. 3) to include predictions of drag. There are, in addition, several other methods available for low supersonic speeds. All of these methods are, in general, based on linear theory and they have been found to be adequate for predicting the aerodynamic forces and moments (with the possible exception of hinge moments) for wing-body combinations, subject, of course, to the usual restrictions of linear theory.

At high supersonic speeds, however, the situation is not so encouraging. There is not, at present, any mass of data available on the aerodynamic characteristics of all-movable wing-body combinations nor any well-established theory. Since the theoretical methods used at lower speeds are, as noted, based on linear theory, their application at high supersonic speeds is often suspect. More comparisons with experimental data are required before the limitations of the linearized methods can be ascertained accurately at high Mach numbers. As a step toward providing the needed experimental data, a program was undertaken to determine the aerodynamic characteristics of two all-movable wing controls in combination with a slender body of revolution. These controls had rectangular plan forms and were tested at Mach numbers from 3.00 to 6.25, angles of attack up to 25°, and angles of control deflection from -30° to +30°. The results of this investigation are reported herein together with comparisons of the experimental characteristics with those predicted by theory.

SYMBOLS

A aspect ratio (for exposed panels joined together), $\frac{(b - 2r_b)^2}{S}$

b control span

c control chord

C_L	lift coefficient, $\dfrac{\text{lift}}{q\pi r_b{}^2}$
C_D	drag coefficient, $\dfrac{\text{drag}}{q\pi r_b{}^2}$
C_m	pitching-moment coefficient about body nose, $\dfrac{\text{pitching moment}}{q\pi r_b{}^2 l}$
C_{N_c}	control-normal-force coefficient, $\dfrac{\text{control normal force}}{qS}$
C_h	hinge-moment coefficient, $\dfrac{\text{hinge moment}}{qSc}$
l	body length
M	Mach number
q	free-stream dynamic pressure
r	body radius
r_b	body radius at base
S	control plan area, exposed
x	longitudinal coordinate
$\bar{x}$	control center of pressure, fraction of control chord
$\bar{x}_\alpha$	control center of pressure for α variable, $\delta = 0^\circ$, percent of control chord
$\bar{x}_\delta$	control center of pressure for δ variable, $\alpha = 0^\circ$, percent of control chord
α	angle of attack of body
δ	control deflection angle relative to body axis, positive for downward deflection of trailing edge

Subscripts

α	rate of change with angle of attack, $\dfrac{\partial}{\partial\alpha}$, unless otherwise specified
δ	rate of change with control deflection angle, $\dfrac{\partial}{\partial\delta}$, unless otherwise specified

[redacted]

EXPERIMENT

Test Apparatus and Methods

The tests were conducted in the Ames 10- by 14-inch supersonic wind tunnel at Mach numbers of 3.00, 4.23, 5.05, and 6.25. This facility is described in detail in reference 4.

Aerodynamic forces and moments were measured by a three-component strain-gage balance. Forces parallel and perpendicular to the balance axis and moments about the model base were measured directly and resolved to give lift, drag, and pitching moments about the body nose. Hinge moments and forces on the wing perpendicular to the body axis were measured by a two-component strain-gage balance mounted within the test body. Angles of attack greater than $+5^{\circ}$ were obtained by the use of bent sting supports. Tare forces on the stings were essentially eliminated by enclosing the stings in shrouds that extended to within 0.040 inch of the model base. Forces acting on the model base were determined from base-pressure measurements. These forces were subtracted from the measured forces acting on the entire model. The data presented, therefore, represent only the forces acting on the forward portion of the model, exclusive of the base.

Static and dynamic pressures were determined from wind-tunnel calibration data and stagnation pressures measured with a Bourdon type pressure gage. Reynolds numbers based on control chord length were:

Mach number	Reynolds number, million
3.00	1.20
4.23	1.09
5.05	.53
6.25	.23

Models

The models used in this investigation consisted of a slender body of revolution and two sets of all-movable controls. The pertinent dimensions of the models are given in figure 1. The body consisted of a 3/4-power profile nose section (see ref. 5) with a fineness ratio of 3, faired to a cylindrical afterbody having a fineness ratio of 9. The controls had aspect ratios of 4/9 and 1 (for exposed wing panels joined together) and ratios of body radius to wing semispan of 0.6 and 0.4, respectively. Both controls had rectangular plan forms and a 4-percent-thick biconvex airfoil section with a 50-percent-blunt trailing edge. The control hinge-line was located at 50 percent of chord and the gap between wing and body was 0.008 inch. The models were constructed of steel and had polished surfaces.

The models used in this investigation were not intended to represent practical aircraft configurations. The results, nevertheless, provide information on the relative merits of rectangular-plan-form controls and are useful for assessing the applicability of available theories for estimating the aerodynamic characteristics of all-movable wing and body combinations at high supersonic speeds.

Accuracy of Test Results

Variations in Mach number in the test region did not exceed ±0.02 except at the maximum test Mach number of 6.25 where the variation was ±0.04. Deviations in stream Reynolds number for a given Mach number did not exceed ±10,000 from the mean values given in the previous section. The estimated errors in the angle of attack due to uncertainties in corrections for stream angle and for deflections of the model-support system were ±0.2°.

The following table of uncertainties represents the maximum possible errors involved in the measurement of the aerodynamic forces and moments:

Quantity	M = 3.00	M = 4.23	M = 5.05	M = 6.25
C_D	±0.013	±0.02	±0.02	±0.04
C_L	±.013	±.02	±.02	±.04
C_m	±.010	±.02	±.02	±.04
C_h	±.005	±.01	±.01	±.02
C_{N_c}	±.01	±.02	±.02	±.04

RESULTS AND DISCUSSION

Experimental Results

The results obtained in the present investigation are given in tables I and II for the complete range of test variables. The coefficients for the control-body combinations are referenced to the body-base area; whereas the coefficients for the control in the presence of the body are referenced to the control-surface area.

Characteristics of the control-body combinations.- The variations of C_L with α, C_m, and C_D are presented in figure 2 for both configurations tested. The results for both control-body combinations are essentially similar over the range of test parameters, the principal difference being in the magnitude of the control loads. This difference can be largely explained by the difference in control-surface area.

The variations of C_L with α are somewhat nonlinear and generally show increasing lift effectiveness with increasing angle of attack except at large values of $\alpha + \delta$ at $M = 3.00$ and 4.23 where appreciable reductions in lift effectiveness are observed. These reductions in lift effectiveness are also reflected in the drag polars, particularly those for the $A = 4/9$ control.

Control effectiveness.- The variations of lift coefficient with control deflection angles for both configurations at several angles of attack are presented in figure 3 for all test Mach numbers. The results are somewhat nonlinear and generally show only small variations in control effectiveness with angle of attack and control deflection except at large $\alpha + \delta$ and $M = 3.00$ and 4.23, where it is observed that the effectiveness of both controls decreases markedly. Similar results have been observed in test results obtained at lower Mach numbers (see ref. 6).

The $A = 1$ control, which has the larger control-surface area, is, of course, a more powerful control than the $A = 4/9$ control. This is evident in figure 3. The lift coefficients presented in figure 3 are referenced to the base area of the body, however, and do not indicate the effectiveness per unit of control-surface area. A more informative comparison of the two controls has been made in figure 4, where their effectiveness parameters, C_{L_δ} (measured at $\alpha = \delta = 0^\circ$), multiplied by the ratio of body-base area to control-surface area are presented as a function of Mach number. The results show that increasing the aspect ratio increases the control effectiveness (per unit of control-surface area) only at Mach numbers less than 5.0. Above $M = 5.0$ the $A = 4/9$ control has essentially the same effectiveness as the $A = 1$ control. It is also shown in figure 5 that these trends are fairly well predicted by the linear-theory method of reference 2.[1] If the exposed panels were joined together, the $A = 4/9$ control would, of course, be less effective than the $A = 1$ control. The difference is made up by increased interference lift carried on the body. It should be noted that these compensating effects of control-body interference and aspect ratio are not unique to Mach numbers above 5.0 but could occur at other Mach numbers for different combinations of aspect ratio and ratios of body radius to control semispan. It is evident, then, that increasing the aspect ratio does not always increase control effectiveness. It is also evident from figure 4 that control effectiveness, as might be expected, is strongly dependent on Mach number. Large reductions in effectiveness occur as the test Mach number increases from 3.00 to 6.25.

[1]More detailed comparisons of theory and experiment are presented in a later section.

Lift-drag ratio.- The variations of lift-drag ratio with lift coefficient for both configurations at $M = 3.00$ are presented in figure 5. It is observed that the aspect-ratio-1 control provides higher lift-drag ratios at small control deflections, whereas the aspect-ratio-4/9 control provides higher ratios at large control deflections. The change is particularly evident between the curves for $\delta = 0^\circ$ and for $\delta = \pm 30^\circ$. Similar results were obtained at the higher Mach numbers.

Control normal force.- The variations of control-normal-force coefficient with angle of attack and control deflection are presented in figures 6 and 7 for both configurations tested. The results are somewhat nonlinear and tend to show an increase in control normal-force effectiveness, $(C_{N_c})_\alpha$, with increasing $|\alpha + \delta|$. A large part of the nonlinearity in the control normal forces, particularly at the higher Mach numbers, may be attributed to nonlinear variation of pressure coefficient with flow deflection angle. Another possible cause of nonlinearity at large α is the reduction of upwash angle at the control (see refs. 7, 8, and 9). Nonlinear variations of the local body upwash with δ are also possible since, due to the finite length of the chord, the leading and trailing edges of the control are a considerable distance away from the plane of greatest upwash when the controls are deflected to large angles.

Hinge-moment characteristics.- The variations of hinge-moment coefficients with angle of attack and with control deflection angle are shown in figures 8 and 9. In general, the results indicate that the hinge-moment coefficients decrease with increasing Mach number and aspect ratio. In most cases, the variations of hinge moment with α and δ are decidedly nonlinear. The primary sources of nonlinearities are, of course, the same as for the control normal forces. Another source of nonlinearity in the hinge-moment variations is center-of-pressure travel. This point becomes most evident at approximately $\alpha + \delta \geq 30^\circ$ for both controls at all Mach numbers tested (compare, e.g., figs. 6 and 8). For $\alpha + \delta > 30^\circ$, sharp reductions in hinge-moment coefficient are observed with increasing angle of attack, whereas normal-force coefficients continue to increase. A rapid movement of the center of pressure (toward the hinge line) is indicated. Thus, it appears that the controls cannot be closely balanced throughout the test range of angles of attack and control deflections.

Comparisons of Theory and Experiment

Control-body combinations.- The aerodynamic characteristics of the control-body combinations have been estimated by adding theoretical predictions for the controls (including contributions of control-body interference) to the experimental characteristics of the body alone.[2] The theoretical predictions for the controls are based on the linear-theory methods of references 2, 3, and 12. The experimental characteristics of the body alone were reported in reference 13.

Comparisons of the estimated and experimental values of lift, drag, and pitching-moment coefficients at Mach numbers of 3.00 and 6.25 are shown in figures 10 and 11 for both control-body combinations tested. The agreement between theory and experiment is generally good to angles of attack of about 10° to 15°, except at large values of $+\delta$. It is of interest to note that the linear variations of lift and pitching moment are restricted to an exceedingly small range of angles of attack even at $M = 3.00$ and that the use of experimental characteristics for the body in the estimated results has accounted for most of the nonlinearities in the lift and pitching-moment curves of the control-body combinations. The major contribution to the nonlinearities for the body itself is the viscous cross force (see ref. 14).

Control-surface characteristics.- The normal-force characteristics of the controls have been estimated by means of the linear-theory methods of references 2 and 12 and the slender-airfoil shock-expansion method of reference 15.[3] Two sets of calculations were performed with each method: First the control was considered to behave as a wing alone and, second, as a control in the presence of the body. The predicted and measured control normal-force coefficients, C_{N_c}, for the undeflected control, $\delta = 0^{\circ}$, are compared in figure 12. Linear theory with the effects of interference included seems to provide good estimates of the control normal forces at the smaller angles of attack; whereas the shock-expansion method with the effects of interference neglected is generally in agreement with the measurements at the larger angles of attack. Similar trends were noted for the other control deflection angles tested. The values predicted by linear theory (with the effects of interference included) and by the shock-expansion method (with interference effects neglected) are compared with measurements for the complete range of control deflections in figures 13 and 14. These comparisons would seem to indicate that, with increasing values of the hypersonic similarity parameter $M\alpha$, the normal-force characteristics of the control in the presence of the body approach those for the control alone. Such a result would be expected because at larger angles of attack, the flow about the body becomes hypersonic in character (i.e., it can, in the main, be described by Newtonian

[2]No correction was applied to the estimated characteristics of the control-body combinations for the effects of the streamwise gap between control and body. It was believed, on the basis of experimental results presented in references 10 and 11, that the effects of the gap would be negligible.

[3]The effects of the tip region were estimated on the basis of the method of reference 16. Unpublished data for rectangular wings at $M = 3.36$ indicate that the control normal forces predicted by use of this tip correction may be slightly low at the larger angles of attack.

flow concepts (see ref. 17)) and the upwash angle on the side of the body approaches the angle of attack of the body.

Both the linear-theory method and the slender-airfoil shock-expansion method (including an average upwash angle) have been used to estimate the control-surface parameters, $(C_{N_c})_\alpha$, $(C_{N_c})_\delta$, C_{h_α}, and C_{h_δ} (at $\alpha = \delta = 0^\circ$). The comparisons with experiment are shown in figure 15. Both methods provide rather good estimates of $(C_{N_c})_\alpha$ and $(C_{N_c})_\delta$, the normal-force curve slopes for linear theory being slightly lower than for the shock-expansion method due to the fact that linear theory neglects the effect of thickness on lift. Linear theory, however, provides a poor estimate of both C_{h_α} and C_{h_δ}. Linear theory is in error primarily in the prediction of the center of pressure on the control. Much of this error is due to the fact that the theory neglects any effect of airfoil section on center-of-pressure location. The slender-airfoil shock-expansion method, which considers this effect, provides a better estimate of these parameters, though the values of C_{h_α} are still underestimated. This error may be attributed to the tendency for a larger portion of the boundary layer on the body to flow over the control surface when the body is inclined. This flow could cause separation on the lee surface of the control and have a considerable effect on the hinge moments.

CONCLUSIONS

Analysis of the results of force tests on two rectangular-plan-form, all-movable controls of aspect ratios 4/9 and 1 in combination with a slender body of revolution at Mach numbers from 3.00 to 6.25 and Reynolds numbers from 0.23 to 1.2 million has led to the following conclusions:

1. The variations of lift with angle of attack for the control-body combinations are somewhat nonlinear throughout the range of test Mach numbers. The major contributor to the nonlinearities is the body itself. Control normal forces are only slightly nonlinear throughout the range of angles of attack and control deflection. Control hinge moments, however, are linear only at small angles of attack and control deflection.

2. The aspect-ratio-1 control is more effective than the aspect-ratio-4/9 control at Mach numbers less than 5. At Mach numbers of 5 and above, the two controls have essentially the same effectiveness per unit of control-surface area. At small control deflections, the aspect-ratio-1 control is more efficient than the aspect-ratio-4/9 control and provides higher lift-drag ratios at a given lift coefficient. At large control deflections the converse is true.

3. Nonlinearities in control effectiveness are generally small, except at large combined angles of attack and control deflection where

appreciable losses in control effectiveness are found. Control effectiveness decreases rapidly with increasing Mach number in accordance with theoretical predictions.

4. Estimates of the aerodynamic characteristics of the control-body combinations, which combined the experimental characteristics of the body and the linear theory predictions of the contributions of the controls (including wing-body interference), are generally good to angles of attack of about 10° to 15°.

5. Linear theory (including the effect of body upwash) provides good estimates of the control normal forces at small angles of attack and control deflection. At larger angles of attack and control deflection, and, in general, at the higher Mach numbers, control normal forces are generally better predicted by a slender-airfoil shock-expansion method neglecting the effect of interference, indicating that the normal-force characteristics of the control in the presence of the body approach those for the control alone with increasing values of the hypersonic similarity parameter, $M\alpha$.

6. Hinge-moment parameters are influenced to a large extent by the shape of the airfoil section and, hence, are not well predicted by linear theory. A method which considers this effect, the slender-airfoil shock-expansion method, provides better estimates of these parameters.

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TABLE I.- EXPERIMENTAL RESULTS FOR ASPECT-RATIO-4/9 CONTROL-BODY COMBINATION

(a) M = 3.00; M = 4.23

M = 3.00

δ, deg	α, deg	C_L	C_D	C_m	C_h	C_{N_c}	$\bar{x}$
0	-2.1	-0.205	0.183	0.098	-0.0089	-0.040	0.276
	0	-.002	.164	-.003	-.0011	.002	.978
	1.0	.086	.171	-.038	---	---	---
	2.1	---	---	---	.0089	.035	.242
	2.9	.318	.209	-.166	---		---
	5.0	.592	.237	-.318	---		---
	7.0	.927	.300	-.511	---		---
	10.2	1.473	.458	-.789	.0279	.221	.374
	13.3	2.140	.697	-1.193	.0301	.281	.393
	17.8	3.101	1.206	-1.757	.0330	.378	.397
	20.9	3.750	1.667	-2.184	.0432	.439	.402
	24.1	4.437	2.265	-2.714	.0483	.505	.404
-10	-2.1	-.558	.259	.368	-.0292	-.222	.368
	-.1	-.318	.215	.239	-.0228	-.157	.355
	2.0	-.072	.205	.102	-.0149	-.068	.331
	4.9	.287	.214	-.086	---	---	---
	8.0	.714	.278	-.291	.0161	.024	-.163
	10.1	1.123	.369	-.523	.0192	.061	.183
	12.2	1.570	.496	-.784	.0204	.094	.282
	17.2	2.757	1.017	-1.458	.0245	.192	.372
	20.9	3.410	1.455	-1.879	.0279	.244	.386
	25.1	4.132	2.073	-2.298	.0331	.328	.399
10	-2.0	.072	.205	-.102	.0149	.088	.331
	.1	.318	.315	-.239	.0228	.157	.355
	2.1	.558	.259	-.368	.0293	.222	.368
	5.0	.914	.340	-.545	.0492	.283	.326
	8.1	1.376	.481	-.782	.0544	.386	.359
	10.2	1.770	.604	-1.008	.0555	.419	.368
	12.3	2.208	.772	-1.268	.0554	.459	.379
	17.8	3.344	1.431	-1.976	.0573	.543	.395
	21.0	4.015	1.920	-2.412	.0598	.612	.402
	24.2	4.631	2.495	-2.843	.0582	.704	.417
-20	-2.2	-.881	.426	.608	-.0658	-.437	.350
	-.1	-.657	.351	.488	-.0561	-.376	.351
	1.9	-.440	.312	.379	-.0454	-.297	.347
	4.9	-.096	.277	.161	---	---	---
	6.9	.321	.271	-.041	-.0137	-.117	.383
	10.1	.953	.372	-.404	-.0078	-.042	.314
	13.2	1.589	.557	-.766	-.0056	-.003	-1.367
	17.7	2.479	.990	-1.272	.0005	.032	.484
	20.8	3.111	1.378	-1.668	.0035	.060	.442
	25.1	3.980	2.039	-2.241	.0073	.112	.435
20	-1.9	.440	.312	-.379	.0454	.297	.347
	.1	.657	.351	-.488	.0561	.376	.351
	2.2	.881	.426	-.608	.0658	.437	.350
	5.1	1.247	.533	-.800	.0741	.532	.361
	6.6	1.481	.669	-.896	.0734	.592	.376
	10.3	2.034	.867	-1.216	.0632	.639	.401
	13.4	2.598	1.131	-1.541	.0553	.673	.418
	17.9	3.476	1.644	-2.057	.0538	.744	.428
	21.0	3.937	2.046	-2.302	.0490	.818	.440
	25.2	4.413	2.703	-2.543	.0467	.919	.449
-30	-2.2	-1.095	.679	.742	-.0695	-.682	.398
	-.2	-.884	.589	.631	-.0764	-.603	.373
	1.9	-.663	.509	.514	-.0767	-.506	.349
	4.8	-.333	.437	.341	---	---	---
	6.9	.032	.405	.129	---	---	---
	10.0	.701	.456	-.242	-.0405	-.215	.312
	13.2	1.375	.614	-.636	-.0434	-.159	.227
	17.6	2.279	1.017	-1.139	-.0349	-.125	.221
	20.3	2.890	1.395	-1.515	-.0373	-.104	.142
	25.0	3.767	1.985	-2.102	-.0384	-.077	0
30	-1.9	.663	.509	-.514	.0695	.506	.363
	.2	.884	.589	-.631	.0764	.603	.373
	2.2	1.095	.679	-.742	.0767	.682	.388
	5.1	1.385	.850	-.880	.1100	.753	.354
	7.2	1.631	.969	-1.004	.1210	.792	.347
	10.3	2.020	1.064	-1.211	.0860	.786	.391
	13.4	2.486	1.259	-1.472	.0620	.759	.418
	17.9	3.425	1.874	-2.064	.0332	.875	.462
	21.0	4.024	2.389	-2.509	.0371	.954	.461
	25.2	4.553	3.085	-2.854	.0244	1.024	.476

M = 4.23

δ, deg	α	C_L	C_D	C_m	C_h	C_{N_c}	$\bar{x}$
0	-2.0	-0.147	0.129	0.044	0.0012	-0.016	0.575
	0	.012	.110	-.026	.0028	-.003	1.433
	1.0	.095	.099	-.023	.0048	.002	-1.900
	2.0	.190	.113	-.064	.0068	.008	-.350
	4.9	.547	.187	-.277	---	---	---
	8.0	.973	.268	-.485	.0176	.144	.378
	10.0	1.260	.363	-.628	.0209	.169	.376
	12.1	1.589	.487	-.804	.0231	.196	.382
	18.4	2.843	1.134	-1.611	.0351	.284	.376
	20.5	3.275	1.349	-1.880	.0381	.326	.383
	22.6	3.690	1.668	-2.166	.0420	.374	.388
-10	-2.1	-.449	.201	.291	-.0230	-.161	.357
	0	-.234	.167	.185	-.0170	-.111	.347
	2.0	-.027	.164	-.073	-.0130	-.064	.297
	4.9	.358	.172	-.138	---	---	---
	7.9	.794	.279	-.368	.0019	.038	.450
	10.0	1.101	.350	-.526	.0048	.058	.417
	12.0	1.420	.454	-.692	.0094	.071	.367
	18.4	2.513	.982	-1.338	.0162	.125	.370
	20.5	2.887	1.230	-1.576	.0176	.157	.388
	22.7	3.281	1.516	-1.836	.0218	.190	.385
10	-2.0	.027	.164	-.073	.0130	.064	.297
	0	.234	.167	-.185	.0170	.111	.347
	2.1	.449	.201	-.291	.0230	.160	.356
	2.9	.558	.220	-.341	.0361	.160	.274
	5.0	.795	.270	-.459	.0442	.195	.273
	7.0	1.101	.339	-.635	.0448	.223	.299
	8.0	1.176	.385	-.628	.0301	.292	.397
	10.0	1.512	.490	-.821	.0322	.322	.400
	12.1	1.885	.629	-1.042	.0342	.352	.403
	18.5	3.112	1.338	-1.844	.0550	.459	.380
	20.5	3.528	1.640	-2.124	.0572	.511	.388
	22.6	3.951	1.993	-2.431	.0575	.577	.400
-20	-2.1	-.701	.334	.473	-.0436	-.339	.371
	0	-.479	.272	.354	-.0390	-.273	.357
	2.0	-.256	.242	.236	-.0321	-.217	.352
	2.9	-.156	.230	.181	---	---	---
	4.9	.150	.217	.005	---	---	---
	6.9	.501	.244	-.203	---	---	---
	7.9	.699	.278	-.272	-.0145	-.078	.314
	10.0	.963	.356	-.432	-.0124	-.062	.300
	12.0	1.271	.462	-.595	-.0114	-.046	.252
	18.4	2.356	.991	-1.222	-.0074	-.007	-.557
	20.4	2.700	1.220	-1.435	-.0049	.005	1.500
	22.5	3.057	1.486	-1.670	-.0041	.019	.722
20	-2.0	.256	.242	-.236	.0321	.217	.352
	0	.479	.272	-.354	.0390	.273	.357
	2.1	.701	.334	-.473	.0436	.339	.371
	3.0	.792	.365	-.511	---	---	---
	5.0	1.023	.433	-.621	---	---	---
	7.0	1.292	.517	-.771	---	---	---
	8.0	1.485	.578	-.885	.0486	.469	.396
	10.1	1.789	.701	-1.055	.0440	.497	.412
	12.1	2.112	.863	-1.241	.0423	.533	.421
	18.5	3.280	1.579	-1.994	.0371	.674	.445
	20.6	3.690	1.906	-2.283	.0318	.748	.458
	22.6	4.066	2.307	-2.560	.0280	.828	.466
-30	-2.1	-.950	.586	.647	-.0689	-.584	.382
	-.1	-.751	.488	.545	-.0669	-.502	.367
	2.0	-.514	.427	.414	-.0609	-.425	.357
	2.9	-.393	.397	.336	---	---	---
	4.9	-.065	.349	.159	---	---	---
	6.9	.282	.321	-.060	---	---	---
	7.9	.463	.357	-.143	-.0458	-.234	.304
	10.0	.778	.419	-.314	-.0467	-.210	.278
	12.0	1.097	.511	-.488	-.0474	-.199	.262
	18.4	2.166	1.029	1.179	-.0440	-.173	.246
	20.4	2.511	1.273	-1.360	-.0455	-.170	.232
	22.5	2.868	1.538	-1.600	-.0480	-.165	.209
30	-2.0	.514	.427	-.414	.0609	.425	.357
	.1	.751	.488	-.545	.0667	.502	.367
	2.1	.950	.586	-.647	.0689	.584	.382
	3.0	1.121	.633	-.754	.1040	.572	.318
	5.0	1.335	.706	-.874	.1100	.583	.311
	7.0	1.536	.782	-.978	.1110	.560	.302
	8.0	1.601	.798	-.974	.0686	.636	.392
	10.1	1.874	.921	-1.125	.0571	.708	.419
	12.1	2.177	1.087	-1.343	.0501	.701	.429
	18.5	3.288	1.846	-2.033	.0159	.874	.482
	20.6	3.668	2.160	-2.308	.0087	.926	.491
	22.6	4.010	2.520	-2.575	.0023	.973	.498

TABLE I.- EXPERIMENTAL RESULTS FOR ASPECT-RATIO-4/9 CONTROL-BODY COMBINATION - Concluded.

(b) M = 5.05; M = 6.25

	M = 5.05							M = 6.25						
δ, deg	α, deg	C_L	C_D	C_m	C_h	C_{N_c}	$\bar{x}$	α	C_L	C_D	C_m	C_h	C_{N_c}	$\bar{x}$
0	-2.0	-0.181	0.119	0.100	-0.0044	-0.032	0.393	-2.0	-0.149	0.147	0.054	-0.0027	-0.012	-0.164
	0	.008	.111	-.008	0	-.003	.845	0	.001	.140	.008	0	.007	1.162
	2.0	.169	.129	-.067	.0046	.025	.274	2.0	.153	.150	-.050	.0050	.026	.500
	2.9	.311	.144	-.147	- - -	- - -	- - -	4.9	.491	.197	-.270	- - -	- - -	- - -
	4.9	.552	.182	-.275	- - -	- - -	- - -	7.9	.792	.291	-.396	.0160	.081	.302
	6.9	.827	.242	-.429	- - -	- - -	- - -	9.9	1.012	.367	-.521	.0180	.101	.322
	7.9	.886	.281	-.424	.0110	.118	.407	11.9	1.250	.464	-.667	.0210	.131	.340
	9.9	1.148	.375	-.552	.0120	.146	.418	18.1	2.293	1.010	-1.342	.0241	.228	.394
	11.9	1.437	.497	-.703	.0140	.178	.421	20.1	2.612	1.238	-1.532	.0282	.278	.399
	18.3	2.683	1.179	-1.470	.0243	.259	.406	22.2	3.012	1.532	-1.758	.0313	.326	.404
	20.3	3.049	1.332	-1.742	.0262	.308	.415							
	22.3	3.469	1.653	-2.034	.0308	.362	.415							
-10	-2.0	-.371	.190	.208	-.0150	-.146	.404	-2.0	-.346	.182	.192	-.0130	-.106	-.425
	0	-.156	.153	.100	-.0110	-.092	.391	0	-.164	.153	.101	-.0110	-.056	.393
	2.0	.038	.150	.006	-.0080	-.055	.373	2.0	.008	.147	.016	-.0100	-.034	.353
	2.9	.186	.157	-.082	- - -	- - -	- - -	8.0	.680	.264	-.252	-.0010	.007	.643
	4.9	.428	.182	-.206	- - -	- - -	- - -	10.0	.915	.318	-.436	.0020	.019	.393
	6.9	.692	.226	-.347	- - -	- - -	- - -	12.0	1.141	.410	-.551	.0030	.032	.406
	7.9	.747	.259	-.332	-.0010	.017	.441	18.1	2.100	.878	-1.184	.0056	.056	.442
	9.9	1.016	.339	-.465	.0010	.029	.447	20.1	2.449	1.099	-1.432	.0128	.120	.393
	11.9	1.290	.403	-.606	.0020	.044	.455	22.2	2.808	1.377	-1.659	.0143	.155	.408
	18.2	2.365	.952	-1.226	.0131	.106	.376							
	20.3	2.735	1.196	-1.454	.0119	.144	.417							
	22.3	3.133	1.474	-1.718	.0209	.166	.374							
10	-2.0	-.038	.150	-.006	.0070	.056	.375	-2.0	-.008	.147	-.016	.0100	.034	.353
	0	.156	.153	-.100	.0100	.092	.391	0	.164	.153	-.101	.0110	.056	.393
	2.0	.371	.190	-.208	.0140	.146	.404	2.0	.346	.182	-.192	.0130	.106	.425
	2.9	.553	.209	-.362	.0402	.131	.193	7.9	.996	.373	-.536	.0130	.219	.441
	4.9	.791	.261	-.486	.0438	.167	.238	9.9	1.226	.478	-.657	.0220	.243	.410
	6.9	1.059	.329	-.630	.0508	.187	.228	12.0	1.462	.606	-.800	.0230	.280	.418
	7.9	1.133	.351	-.618	.0204	.232	.412	18.1	2.450	1.220	-1.483	-.0015	.463	.503
	9.9	1.420	.494	-.776	.0268	.257	.396	20.2	2.819	1.523	-1.740	-.0142	.530	.527
	11.9	1.706	.631	-.925	.0321	.285	.387	22.2	3.242	1.896	-2.042	-.0112	.577	.519
	18.3	2.802	1.309	-1.600	.0463	.436	.394							
	20.3	3.178	1.612	-1.858	.0457	.503	.409							
	22.3	3.607	1.940	-2.162	.0505	.569	.411							
-20	-2.0	-.660	.308	.433	-.0322	-.317	.399	-2.0	-.515	.256	.349	-.0327	-.199	.336
	0	-.418	.240	.307	-.0298	-.243	.377	0	-.273	.208	.193	-.0362	-.125	.210
	2.0	-.203	.211	.207	-.0276	-.195	.359	2.0	-.096	.201	.117	-.0301	-.131	.270
	2.9	-.124	.221	.105	- - -	- - -	- - -	4.9	.204	.192	-.055	-.1039	-.003	-34.1
	4.9	.236	.222	-.052	- - -	- - -	- - -	7.9	.536	.267	-.218	-.0825	-.067	.164
	6.9	.335	.255	-.224	- - -	- - -	- - -	9.9	.716	.345	-.315	-.0220	-.052	.073
	7.9	.637	.289	-.260	-.0190	-.076	.250	11.9	.943	.446	-.505	-.0210	-.040	-.024
	9.9	.908	.357	-.401	-.0163	-.057	.214	18.1	1.882	.942	-1.043	-.0195	-.013	-.988
	11.9	1.191	.458	-.557	-.0147	-.046	.181	20.1	2.205	1.153	-1.279	-.0180	-.001	-19.5
	18.2	2.208	.972	-1.131	-.0073	-.019	.117	22.2	2.563	1.421	-1.500	-.0149	.012	1.796
	20.3	2.548	1.195	-1.337	-.0090	.002	6.113							
	22.3	2.917	1.456	-1.585	-.0102	.015	1.180							
20	-2.0	.203	.211	-.207	.0276	.195	.359	-2.0	.096	.202	-.117	.0301	.131	.270
	0	.418	.240	-.307	.0298	.243	.377	0	.273	.208	-.193	.0362	.125	.210
	2.0	.660	.308	-.433	.0322	.317	.398	2.0	.515	.256	-.349	.0327	.199	.336
	2.9	.792	.348	-.518	.0356	.357	.400	4.9	.846	.362	-.531	- - -	- - -	- - -
	4.9	1.014	.419	-.631	.0368	.407	.410	7.9	1.202	.515	-.719	.0210	.375	.444
	6.9	1.258	.495	-.765	.0346	.431	.420	9.9	1.473	.640	-.892	.0210	.417	.450
	7.9	1.433	.556	-.858	.0356	.436	.418	11.9	1.752	.779	-1.082	.0140	.471	.470
	10.0	1.708	.686	-1.012	.0318	.481	.434	18.2	2.790	1.481	-1.762	- - -	- - -	- - -
	12.0	2.025	.849	-1.202	.0277	.526	.447	20.2	3.168	1.787	-2.033	- - -	- - -	- - -
	18.3	2.973	1.661	-1.792	.0243	.675	.464	22.2	3.601	2.182	-2.350	- - -	- - -	- - -
	20.3	3.452	1.958	-2.144	.0229	.749	.470							
	22.3	3.928	2.296	-2.499	.0229	.832	.473							
-30	-2.1	-.815	.527	.548	-.0716	-.518	.362	-2.0	-.728	.411	.485	- - -	- - -	- - -
	0	-.650	.439	.491	-.0692	-.436	.341	0.0	-.478	.379	.361	- - -	- - -	- - -
	2.0	-.461	.420	.397	-.0648	-.406	.340	2.0	-.356	.345	.308	- - -	- - -	- - -
	2.9	-.301	.393	.274	- - -	- - -	- - -	4.9	.025	.365	.034	- - -	- - -	- - -
	4.9	.011	.366	.091	- - -	- - -	- - -	7.9	.403	.411	-.148	- - -	- - -	- - -
	6.9	.318	.373	-.091	- - -	- - -	- - -	9.9	.604	.471	-.267	- - -	- - -	- - -
	7.9	.464	.396	-.155	-.0590	-.218	.229	11.9	.804	.544	-.396	- - -	- - -	- - -
	9.9	.737	.448	-.299	-.0590	-.207	.215	18.1	1.692	.949	-.910	- - -	- - -	- - -
	11.9	1.018	.528	-.452	-.0600	-.200	.200	20.1	1.978	1.164	-1.104	- - -	- - -	- - -
	18.2	1.985	1.033	-1.020	-.0564	-.189	.202	22.1	2.375	1.424	-1.377	- - -	- - -	- - -
	20.2	2.335	1.257	-1.239	-.0622	-.188	.169							
	22.3	2.684	1.520	-1.472	-.0562	-.204	.225							
30	-2.0	.461	.420	-.397	.0648	.406	.340	-2.0	.356	.345	-.308	- - -	- - -	- - -
	0	.650	.439	-.491	.0692	.436	.341	.0	.478	.329	-.361	- - -	- - -	- - -
	2.1	.815	.527	-.548	.0716	.518	.362	2.0	.728	.411	-.485	- - -	- - -	- - -
	2.9	1.070	.373	-.711	- - -	- - -	- - -	4.9	1.102	.475	-.759	- - -	- - -	- - -
	4.9	1.266	.437	-.807	- - -	- - -	- - -	7.9	1.501	.614	-.980	- - -	- - -	- - -
	7.9	1.604	.718	-.992	.0507	.617	.418	9.9	1.755	.756	-1.137	- - -	- - -	- - -
	9.9	1.987	.870	-1.175	.0421	.654	.436	11.9	2.034	.932	-1.333	- - -	- - -	- - -
	12.0	2.196	1.062	-1.364	.0363	.696	.448	18.2	3.082	1.818	-2.005	- - -	- - -	- - -
	18.3	3.360	1.903	-2.121	- - -	- - -	- - -	20.2	3.240	2.087	-2.038	- - -	- - -	- - -
	20.3	3.638	2.220	-2.295	- - -	- - -	- - -	22.2	3.637	2.541	-2.358	- - -	- - -	- - -
	22.4	3.960	2.587	-2.529	- - -	- - -	- - -							

TABLE II.- EXPERIMENTAL RESULTS FOR ASPECT-RATIO-1 CONTROL-BODY COMBINATION

(a) M = 3.00; M = 4.23

	M = 3.00							M = 4.23						
δ, deg	α, deg	C_L	C_D	C_m	$-C_h$	C_{N_c}	$\bar{x}$	α	C_L	C_D	C_m	C_h	C_{N_c}	$\bar{x}$
0	-2.1	-0.352	0.213	0.220	-0.0064	-0.058	0.390	-2.0	-0.308	0.165	0.183	-0.0019	-0.048	0.461
	0	-.016	.181	.021	-.0008	-.024	.467	0	-.030	.148	.018	.0029	-.008	.854
	1.0	.146	.190	-.076	.0034	.023	.352	2.0	.248	.161	-.145	.0082	.031	.234
	2.1	.320	.206	-.179	.0036	.052	.431	2.9	.406	.173	-.252	---	---	---
	4.2	.700	.252	-.409	.0062	.114	.446	5.0	.716	.210	-.423	---	---	---
	7.2	1.408	.386	-.826	.0220	.213	.397	7.0	1.082	.268	-.635	---	---	---
	10.3	2.178	.603	-1.297	.0260	.291	.411	8.0	1.325	.356	-.724	.0170	.155	.390
	13.5	3.000	.923	-1.806	.0310	.363	.415	10.1	1.717	.477	-.955	.0200	.186	.393
	18.0	4.160	1.589	-2.530	.0379	.480	.421	12.1	2.130	.628	-1.198	.0220	.222	.401
	21.2	4.566	2.105	-2.683	.0439	.564	.422	18.5	3.513	1.444	-2.119	.0292	.348	.416
								20.6	4.045	1.757	-2.475	.0326	.402	.419
								22.7	4.586	2.168	-2.877	.0374	.467	.420
-10	-4.4	-1.581	.510	1.065	-.0289	-.353	.418	-2.1	-.837	.293	.570	-.0158	-.202	.422
	-2.3	-1.181	.396	.816	-.0243	-.277	.412	-.1	-.527	.228	.387	-.0120	-.148	.419
	-.2	-.812	.303	.594	-.0184	-.211	.413	2.0	-.230	.201	.214	-.0080	-.101	.421
	2.0	-.420	.260	.369	-.0136	-.135	.399	2.9	-.087	.183	.114	---	---	---
	4.9	.140	.218	.012	-.0048	-.049	.402	4.9	.251	.180	-.082	---	---	---
	7.0	.596	.265	-.231	.0030	.010	.200	6.9	.604	.215	-.236	---	---	---
	10.2	1.325	.387	-.655	.0110	.080	.363	8.0	.814	.233	-.378	.0012	.012	.400
	13.4	2.091	.610	-1.108	.0140	.140	.400	10.0	1.172	.318	-.576	.0040	.032	.375
	17.8	3.227	1.153	-1.812	.0184	.219	.416	12.0	1.542	.433	-.784	.0060	.054	.389
	21.0	4.018	1.637	-2.335	.0213	.282	.426	18.4	2.776	1.069	-1.519	.0129	.138	.407
	24.2	4.657	2.197	-2.718	.0258	.355	.427	20.5	3.260	1.346	-1.845	.0154	.172	.411
								22.6	3.694	1.659	-2.129	.0197	.209	.406
10	-2.0	.420	.260	-.369	.0136	.135	.399	-2.0	.230	.201	-.214	.0080	.101	.421
	.2	.812	.303	-.594	.0184	.211	.413	.1	.527	.228	-.387	.0120	.148	.419
	2.3	1.181	.396	-.816	.0243	.277	.422	2.1	.837	.293	-.570	.0158	.202	.422
	4.4	1.581	.510	-1.065	.0289	.353	.418	3.0	1.030	.283	-.697	---	---	---
	7.3	2.177	.764	-1.385	.0486	.467	.396	5.0	1.347	.413	-.887	---	---	---
	10.5	2.877	1.064	-1.819	.0559	.543	.397	7.0	1.705	.537	-1.058	---	---	---
	13.7	3.643	1.474	-2.318	.0604	.621	.403	8.1	2.010	.622	-1.254	.0341	.351	.403
	18.1	4.618	2.048	-2.896	.0579	.745	.422	10.1	2.427	.781	-1.507	.0348	.398	.413
								12.2	2.877	.994	-1.784	.0371	.448	.417
								18.6	4.342	1.819	-2.863	---	---	---
								20.7	4.837	2.199	-3.149	.0586	.696	.425
								22.5	5.444	2.770	-3.645	.0597	.781	.424
-20	-4.5	-2.356	1.023	1.635	-.0643	-.633	.399	-2.2	-1.489	.636	1.038	-.0334	-.435	.423
	-2.4	-2.007	.842	1.417	-.0526	-.561	.406	-.1	-1.161	.505	.837	-.0294	-.363	.419
	-.3	-1.654	.680	1.201	-.0433	-.488	.411	1.9	-.826	.415	.632	-.0212	-.303	.430
	1.8	-1.261	.568	.944	-.0361	-.404	.411	2.8	-.630	.382	.525	---	---	---
	4.8	-.648	.445	.575	-.0319	-.271	.382	4.9	-.229	.327	.269	---	---	---
	6.9	-.097	.380	.250	---	---	---	6.9	.197	.319	0	---	---	---
	10.1	.747	.417	-.266	-.0137	-.087	.343	7.9	.388	.341	-.067	-.0182	-.120	.348
	13.3	1.528	.577	-.716	-.0141	-.029	.014	10.0	.739	.399	-.264	-.0168	-.097	.327
	17.7	2.497	.980	-1.274	-.0107	.047	.728	12.0	1.090	.491	-.457	-.0168	-.079	.287
	20.8	3.204	1.396	-1.757	-.0076	.055	.638	18.4	2.246	1.010	-1.171	-.0153	-.029	-.026
	24.0	3.956	1.912	-2.254	-.0038	.099	.538	20.4	2.639	1.247	-1.424	-.0144	-.014	-.529
								22.5	3.034	1.523	-1.686	-.0114	.004	3.350
20	-1.8	1.261	.568	-.944	.0361	.404	.411	-1.9	.826	.415	-.632	.0212	.303	.430
	.3	1.654	.680	-1.201	.0433	.488	.411	.1	1.161	.505	-.837	.0294	.363	.419
	2.4	2.007	.842	-1.417	.0526	.561	.406	2.2	1.489	.636	-1.038	.0334	.435	.423
	4.5	2.356	1.023	-1.635	.0643	.633	.399	3.0	1.627	.744	-1.105	.0528	.452	.333
	7.5	2.998	1.409	-2.052	.0776	.711	.391	5.1	1.933	.888	-1.297	.0559	.508	.390
	10.6	3.507	1.689	-2.362	.0639	.774	.418	7.1	2.249	1.042	-1.484	.0595	.550	.392
	13.7	4.160	2.106	-2.796	.0553	.843	.435	8.1	2.548	1.113	-1.708	.0424	.585	.428
								10.2	2.937	1.339	-1.969	.0457	.629	.427
								12.2	3.338	1.613	-2.240	.0452	.683	.434
-30	-4.6	-2.836	1.727	2.008	-.0735	-.890	.418	-2.3	-2.125	1.281	1.490	-.0621	-.703	.412
	-2.5	-2.611	1.561	1.879	-.0725	-.824	.412	-.2	-1.809	1.081	1.289	-.0527	-.634	.417
	-.5	-2.318	1.363	1.646	-.0671	-.761	.412	1.9	-1.449	.921	1.052	-.0444	-.548	.419
	1.6	-1.946	1.183	1.419	-.0606	-.673	.410	2.8	-1.249	.883	.892	---	---	---
	4.7	-1.325	.926	.977	---	---	---	4.8	-.841	.738	.638	---	---	---
	6.8	-.801	.785	.664	-.0497	-.454	.391	6.9	-.397	.692	.364	---	---	---
	9.9	.070	.704	.152	---	---	---	7.9	-.160	.634	.278	-.0420	-.321	.369
	13.1	.887	.796	-.340	-.0450	-.242	.314	9.9	.193	.664	.069	-.0440	-.292	.349
	17.6	1.854	1.133	-.904	-.0467	-.196	.262	12.0	.541	.733	-.133	-.0450	-.278	.338
	20.7	2.501	1.493	-1.319	-.0476	-.171	.222	18.3	1.589	1.176	-.796	-.0517	-.246	.290
	23.9	3.176	1.955	-1.771	-.0492	-.145	.161	20.4	1.925	1.382	-1.000	-.0509	-.245	.292
								22.4	2.275	1.625	-1.240	-.0569	-.245	.268
30	-1.6	1.946	1.182	-1.419	.0606	.673	.410	-1.9	1.449	.921	-1.052	.0444	.548	.419
	.5	2.318	1.363	-1.646	.0671	.761	.412	.2	1.809	1.081	-1.289	.0527	.634	.417
	2.5	2.611	1.561	-1.879	.0725	.824	.412	2.3	2.125	1.281	-1.490	.0621	.703	.412
	4.6	2.836	1.727	-2.008	.0735	.890	.418	3.1	2.279	1.436	-1.593	.0689	.754	.382
	7.5	3.295	2.138	-2.285	.0685	1.001	.432	5.1	2.544	1.574	-1.773	.0860	.786	.391
	10.7	3.769	2.467	-2.648	.0398	1.050	.462	7.2	2.802	1.734	-1.952	.0778	.811	.404
	13.9	4.388	2.920	-3.100	.0195	1.112	.483	8.2	3.016	1.877	-2.083	.0462	.808	.443
								10.3	3.348	2.128	-2.315	.0386	.853	.455
								12.3	3.720	2.438	-2.585	.0329	.901	.464

[redacted]

TABLE II.- EXPERIMENTAL RESULTS FOR ASPECT-RATIO-1 CONTROL-BODY COMBINATION - Concluded.

(b) M = 5.05; M = 6.25

	M = 5.05							M = 6.25						
δ, deg	α, deg	c_L	c_D	c_m	c_h	c_{N_c}	$\bar{x}$	α	c_L	c_D	c_m	c_h	c_{N_c}	$\bar{x}$
0	-2.0	-0.254	0.170	-0.121	-0.0027	-0.038	0.429	-2.0	-0.206	0.202	0.113	-0.0055	-0.024	0.270
	0	-.002	.151	-.010	-0.0024	0.001	---	0	-.004	.194	.007	-.0009	-0.001	.400
	2.0	.259	.171	-.149	0.0052	0.029	.317	2.0	.198	.214	-.099	.0014	0.025	.445
	2.9	.396	.176	-.214	---	---	---	4.9	.567	.236	---	---	---	---
	4.9	.689	.218	-.378	---	---	---	7.9	.960	.343	-.521	.0146	.107	.364
	6.9	1.001	.283	-.552	---	---	---	9.9	1.240	.438	-.723	.0175	.136	.371
	7.9	1.217	.362	-.704	.0167	.132	.374	11.9	1.562	.562	-.937	.0212	.170	.375
	10.0	1.556	.469	-.907	.0189	.165	.366	18.2	2.784	1.291	-1.716	.026	.330	.421
	12.0	1.932	.614	-1.143	.0227	.200	.387	20.2	3.261	1.606	-2.064	.0278	.399	.430
	18.3	3.257	1.354	-1.996	.0298	.311	.404	22.2	3.775	1.980	-2.423	.0296	.472	.437
	20.3	3.779	1.699	-2.331	.0325	.377	.414							
	22.4	4.328	2.101	-2.766	.0377	.449	.416							
-10	-2.1	-.743	.280	.469	-.0129	-.173	.426	-2.0	-.618	.294	.432	-.0139	-.141	.402
	0	-.437	.216	.293	-.0084	-.126	.433	.0	-.351	.245	.270	-.0105	-.100	.395
	2.0	-.164	.181	.139	-.0071	-.083	.415	2.0	-.106	.212	.120	-.0075	-.071	.394
	2.9	0	.193	.056	---	---	---	4.9	.291	.186	-.139	---	---	---
	4.9	.300	.192	-.111	---	---	---	7.9	.596	.249	-.145	---	---	---
	6.9	.617	.240	-.291	---	---	---	9.9	.858	.307	-.290	-.0090	.005	2.300
	7.9	.749	.278	-.348	.0042	.003	-.900	11.9	1.093	.393	-.428	-.0040	.024	.667
	9.9	1.059	.355	-.514	.0058	.022	.236	18.1	2.122	1.049	-1.215	.0034	.107	.468
	12.0	1.379	.455	-.686	.0056	.046	.378	20.2	2.569	1.208	-1.526	.0068	.139	.451
	18.2	2.565	1.052	-1.405	.0098	.114	.414	22.2	3.081	1.476	-1.875	.0112	.177	.437
	20.3	3.000	1.307	-1.697	.0101	.151	.433							
	22.3	3.456	1.611	-2.009	.0133	.193	.431							
10	-2.0	.164	.181	-.139	.0071	.083	.415	-2.0	.106	.212	-.120	.0075	.071	.394
	0	.437	.216	-.293	.0084	.126	.433	.0	.351	.245	-.270	.0105	.100	.395
	2.1	.743	.280	-.469	.0129	.173	.426	2.0	.618	.294	-.432	.0139	.141	.402
	2.9	1.220	.270	-.894	---	---	---	7.9	1.564	.547	-.999	.0250	.298	.403
	4.9	1.236	.378	-.775	---	---	---	9.9	1.954	.695	-1.271	.0270	.308	.412
	7.0	1.593	.477	-.990	---	---	---	11.9	2.320	.875	-1.522	.0290	.368	.421
	8.0	1.752	.558	-1.067	.0275	.305	.410	18.2	3.613	1.819	-2.285	---	---	---
	10.0	2.130	.723	-1.327	.0304	.354	.414	20.2	4.183	2.276	-2.705	---	---	---
	12.0	2.527	.932	-1.584	.0333	.408	.418	22.2	4.762	2.761	-3.149	---	---	---
	18.3	4.100	1.950	-2.623	.0385	.582	.434							
	20.4	4.688	2.409	-3.053	.0371	.681	.446							
	22.4	5.300	2.936	-3.529	.0427	.782	.445							
-20	-2.1	-1.376	.583	.923	-.0388	-.392	.401	-2.0	-1.132	.528	.816	-.0327	-.321	.398
	-.1	-1.009	.460	.709	-.0357	-.318	.388	.0	-.825	.425	.619	-.0322	-.258	.375
	2.0	-.678	.389	.513	-.0321	-.260	.377	2.0	-.554	.374	.433	-.0313	-.221	.358
	2.9	-.466	.356	.377	-.0267	-.231	.365	7.9	.269	.350	-.038	-.0220	-.132	.333
	4.9	-.105	.333	.166	-.0253	-.173	.354	9.9	.536	.387	-.218	-.0210	-.118	.322
	6.9	.224	.390	-.024	-.0226	-.142	.341	11.9	.813	.450	-.421	-.0230	-.103	.277
	7.9	.396	.374	-.117	-.0206	-.121	.330	18.1	1.685	1.002	-.829	-.0198	-.088	.275
	9.9	.686	.429	-.281	-.0201	-.103	.305	20.1	2.019	1.241	-1.102	-.0189	-.084	.275
	11.9	.998	.513	-.462	.0185	-.090	.295	22.2	2.426	1.524	-1.427	-.0155	-.068	.272
	18.2	2.054	1.026	-1.038	-.0184	-.051	.139							
	20.2	2.435	1.257	-1.277	-.0148	-.045	.171							
	22.3	2.829	1.524	-1.542	-.0143	-.030	.023							
20	-2.0	.678	.389	-.513	.0321	.260	.377	-2.0	.554	.374	-.433	.0313	.221	.358
	.1	1.009	.460	-.709	.0357	.318	.388	.0	.825	.425	-.619	.0322	.258	.375
	2.1	1.376	.583	-.923	.0388	.392	.401	2.0	1.132	.528	-.816	.0327	.321	.398
	2.9	1.552	.664	-1.040	.0525	.397	.368	7.9	2.144	.941	-1.466	.0401	.469	.415
	5.0	1.887	.788	-1.252	.0557	.457	.378	9.9	2.500	1.151	-1.726	.0390	.548	.429
	7.0	2.235	.960	-1.465	.1092	.511	.287	12.0	2.920	1.421	-2.065	.0340	.633	.446
	8.0	2.436	1.095	-1.571	.0476	.552	.414							
	10.0	2.813	1.314	-1.809	.0485	.608	.420							
	12.1	3.249	1.588	-2.124	.0524	.672	.422							
-30	-2.1	-1.932	1.137	1.331	-.0522	-.681	.423	-2.0	-1.729	1.037	1.270	---	---	---
	-.1	-1.594	.963	1.127	-.0557	-.599	.407	0	-1.395	.872	1.036	---	---	---
	1.9	-1.306	.875	.949	-.0536	-.554	.403	2.0	-1.195	.810	.899	---	---	---
	2.8	-.997	.805	.704	---	---	---	4.9	-.717	.708	---	---	---	---
	4.9	-.636	.733	.498	---	---	---	7.8	-.366	.658	.264	---	---	---
	6.9	-.355	.657	.361	---	---	---	9.9	-.061	.689	.148	---	---	---
	7.9	-.174	.664	.245	-.0470	-.321	.354	11.9	.143	.753	.017	---	---	---
	9.9	.118	.693	.107	-.0500	-.303	.335	18.1	.971	1.198	-.479	---	---	---
	11.9	.413	.762	-.104	-.0540	-.285	.311	20.1	1.158	1.406	-.618	---	---	---
	18.2	1.392	1.226	-.670	-.0580	-.285	.297	22.1	1.480	1.661	-.825	---	---	---
	20.2	1.700	1.424	-.864	-.0609	-.294	.293							
	22.2	2.018	1.664	-1.079	-.0635	-.306	.293							
30	-1.9	1.306	.875	-.949	.0536	.554	.403	-2.0	1.195	.810	-.899	---	---	---
	.1	1.594	.963	-1.127	.0557	.599	.407	0	1.395	.872	-1.036	---	---	---
	2.1	1.932	1.137	-1.331	.0522	.681	.423	2.0	1.729	1.037	-1.270	---	---	---
	3.0	2.169	1.302	-1.498	.0749	.726	.397	4.9	2.192	1.293	---	---	---	---
	5.0	2.444	1.489	-1.668	.0773	.772	.400	7.9	2.611	1.636	-1.863	---	---	---
	7.0	2.743	1.700	-1.862	.0738	.819	.410	9.9	2.948	1.920	-2.125	---	---	---
	8.0	2.944	1.788	-2.009	.0500	.759	.434	11.9	3.342	2.258	-2.477	---	---	---
	10.0	3.279	2.048	-2.241	.0449	.808	.446							
	12.1	3.687	2.382	-2.561	.0384	.875	.456							

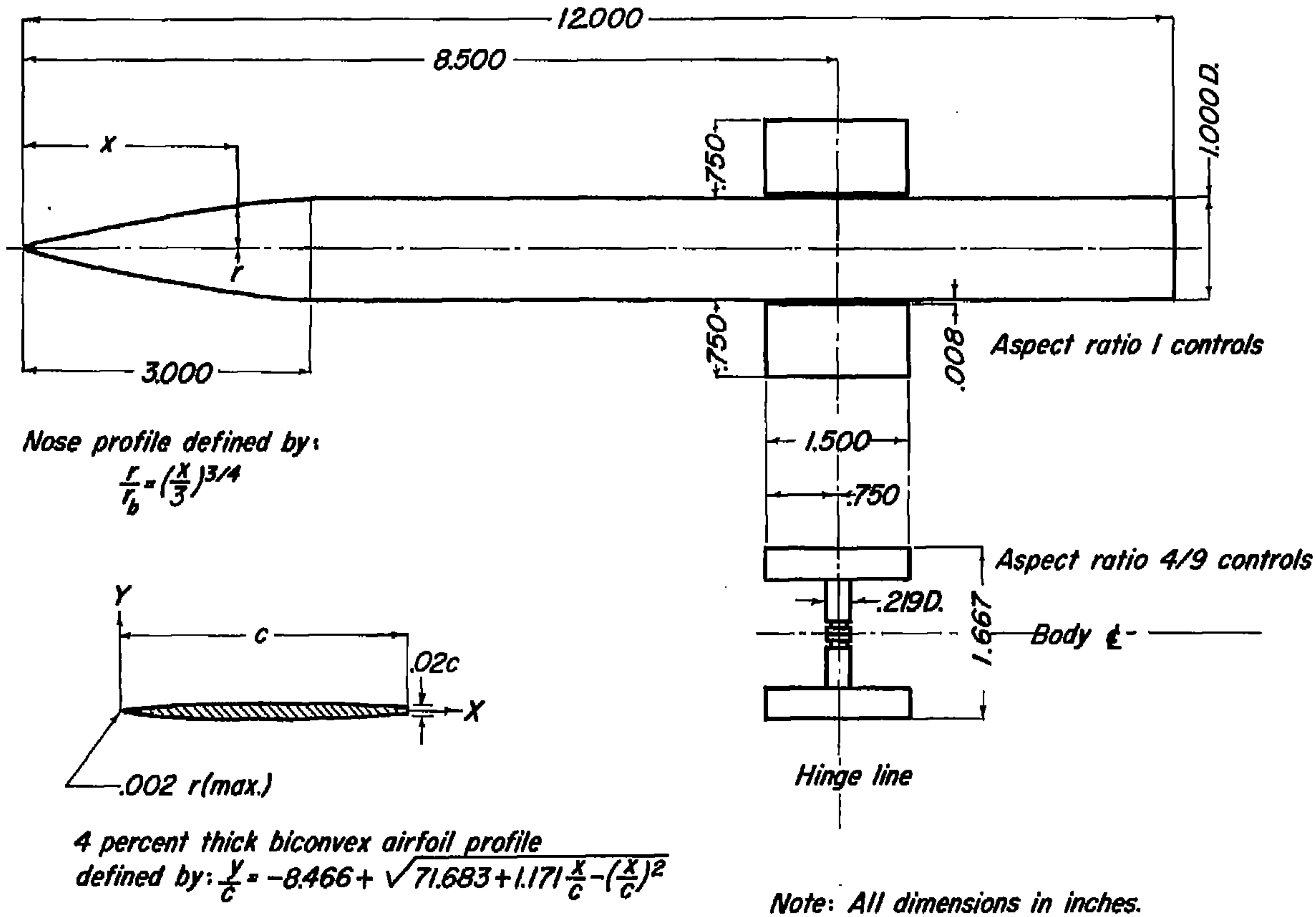
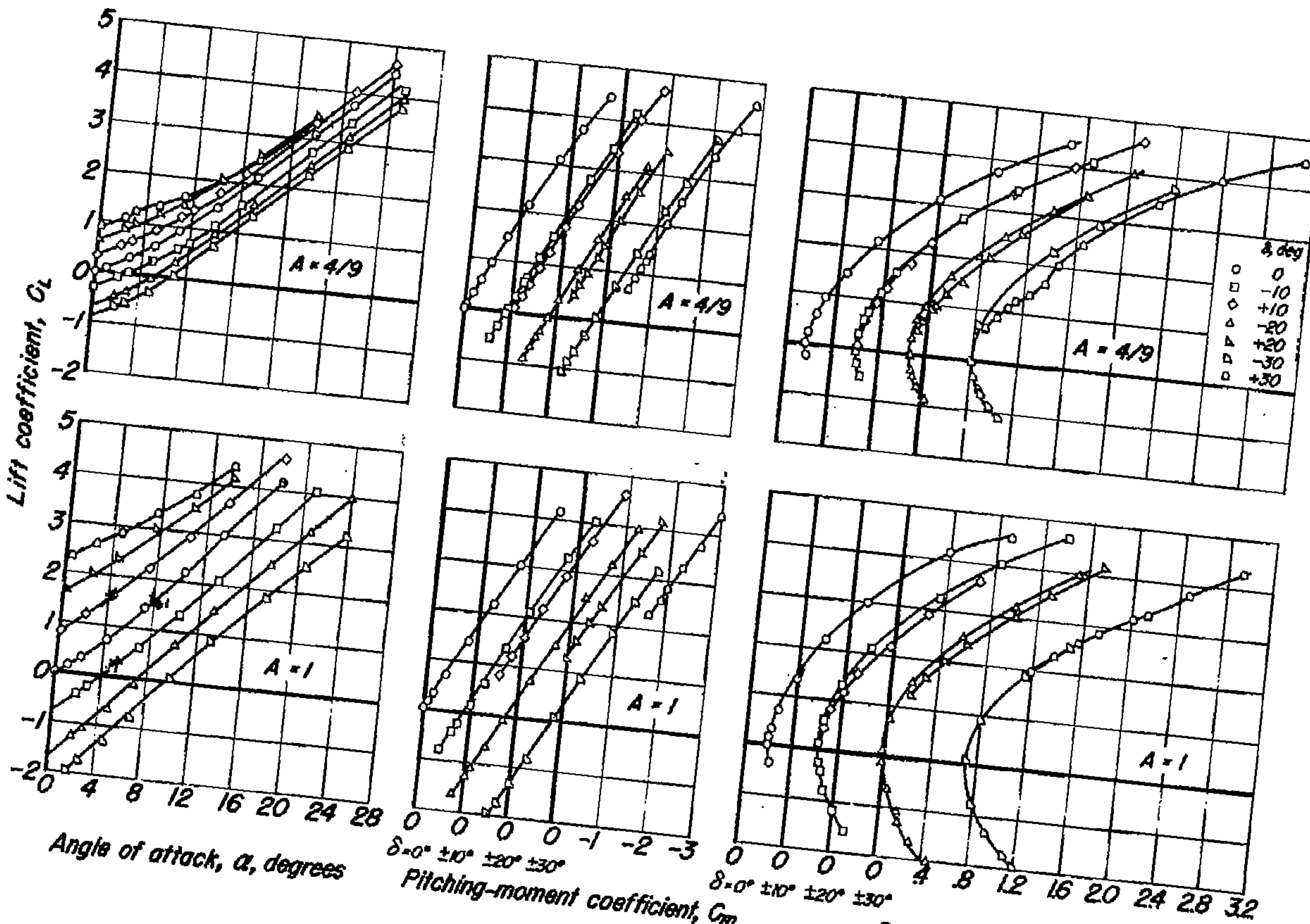


Figure 1.– Details of control-body combinations tested.

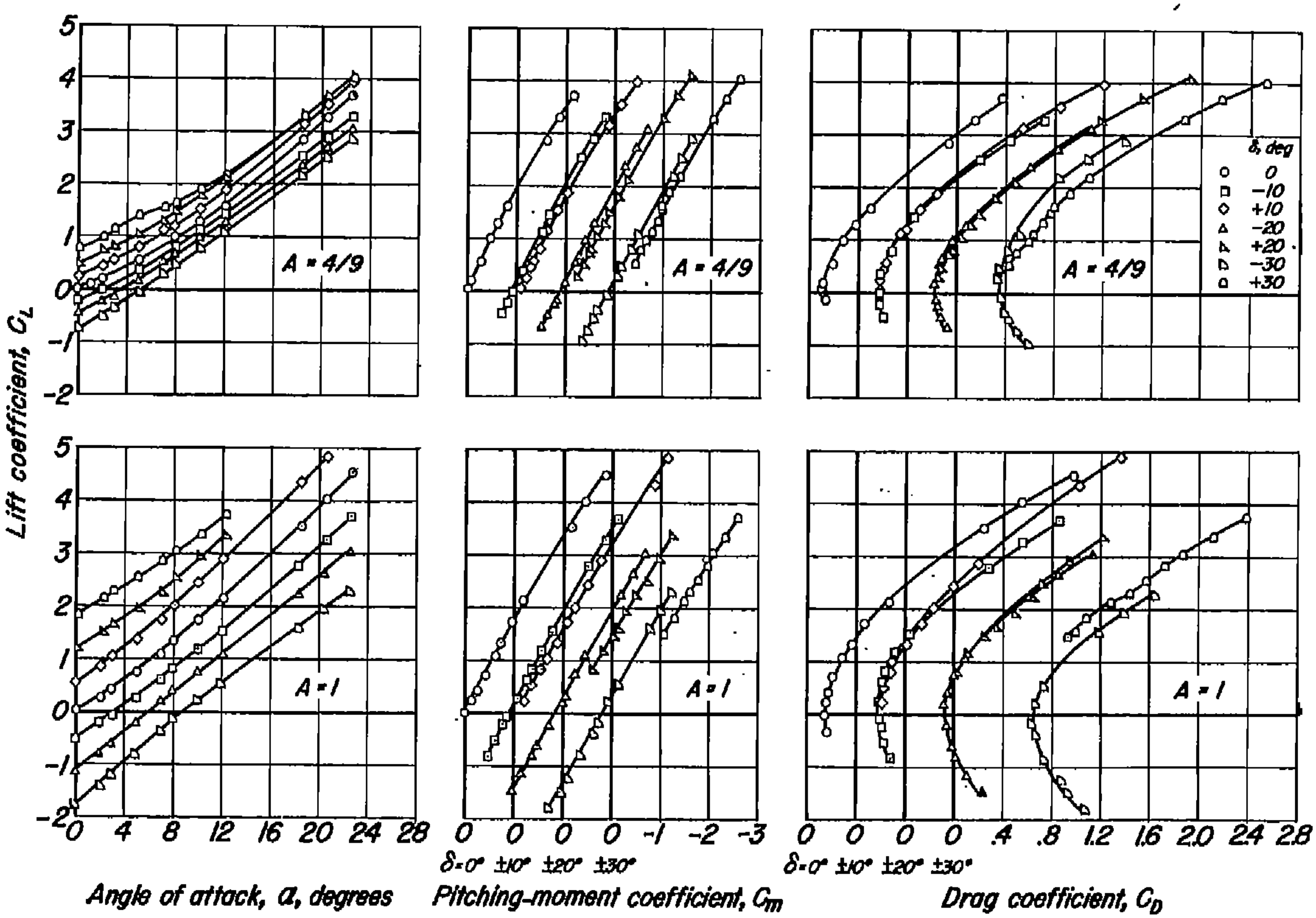
[redacted]



(a) $M = 3.00$

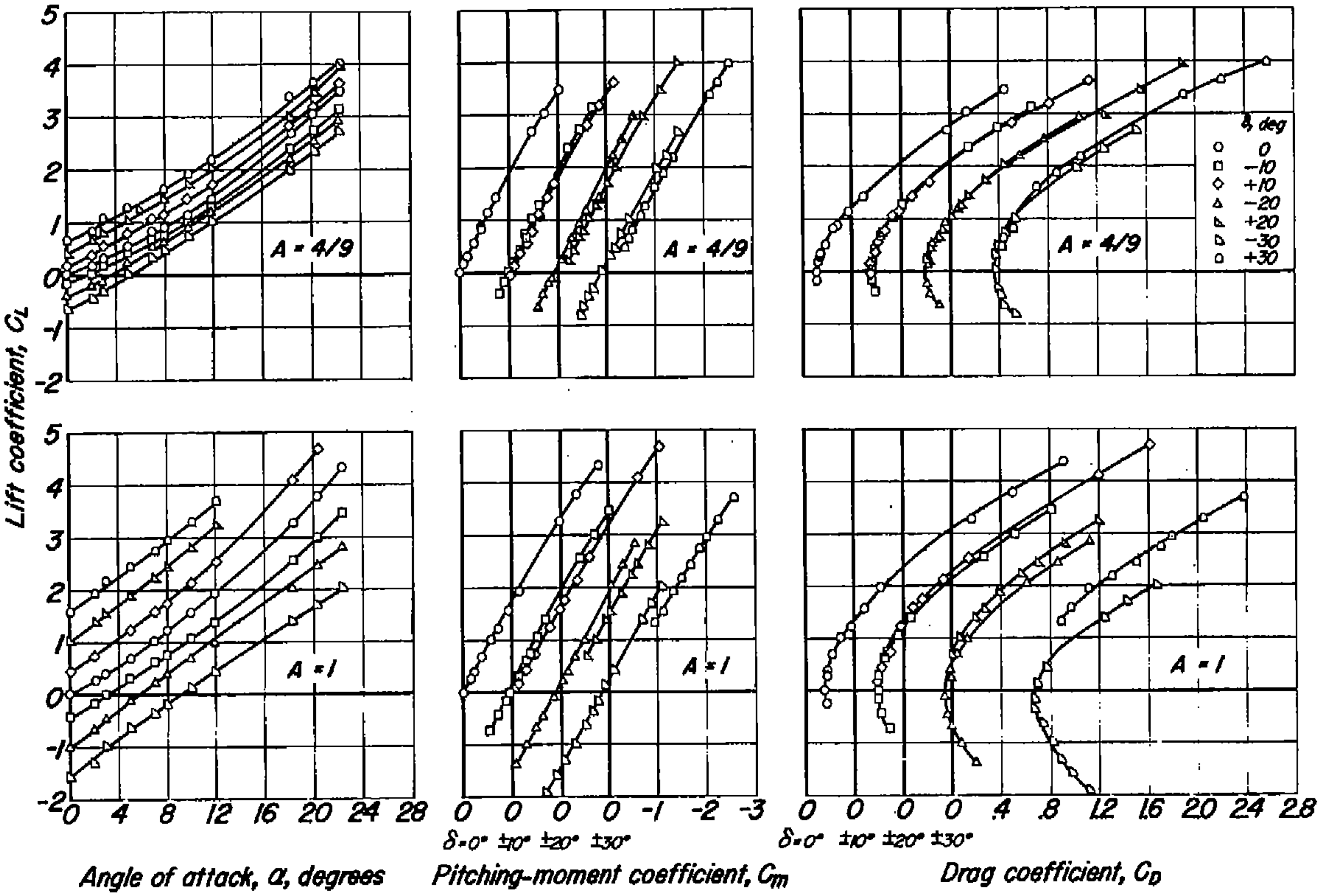
Figure 2.– Aerodynamic characteristics of the $A = 4/9$ and $A = 1$ control-body combinations.

[redacted]



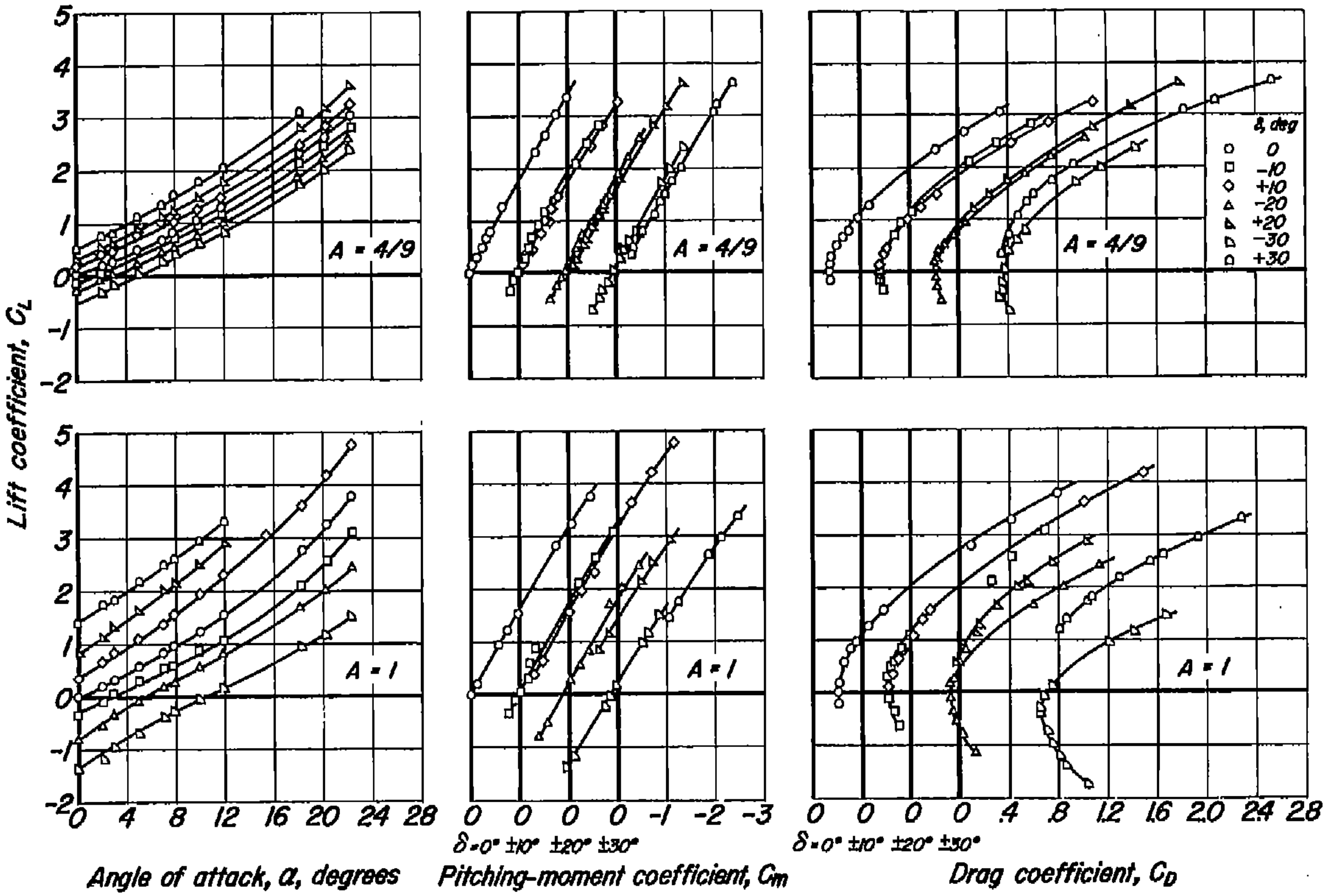
(b) M = 4.23

Figure 2.– Continued.



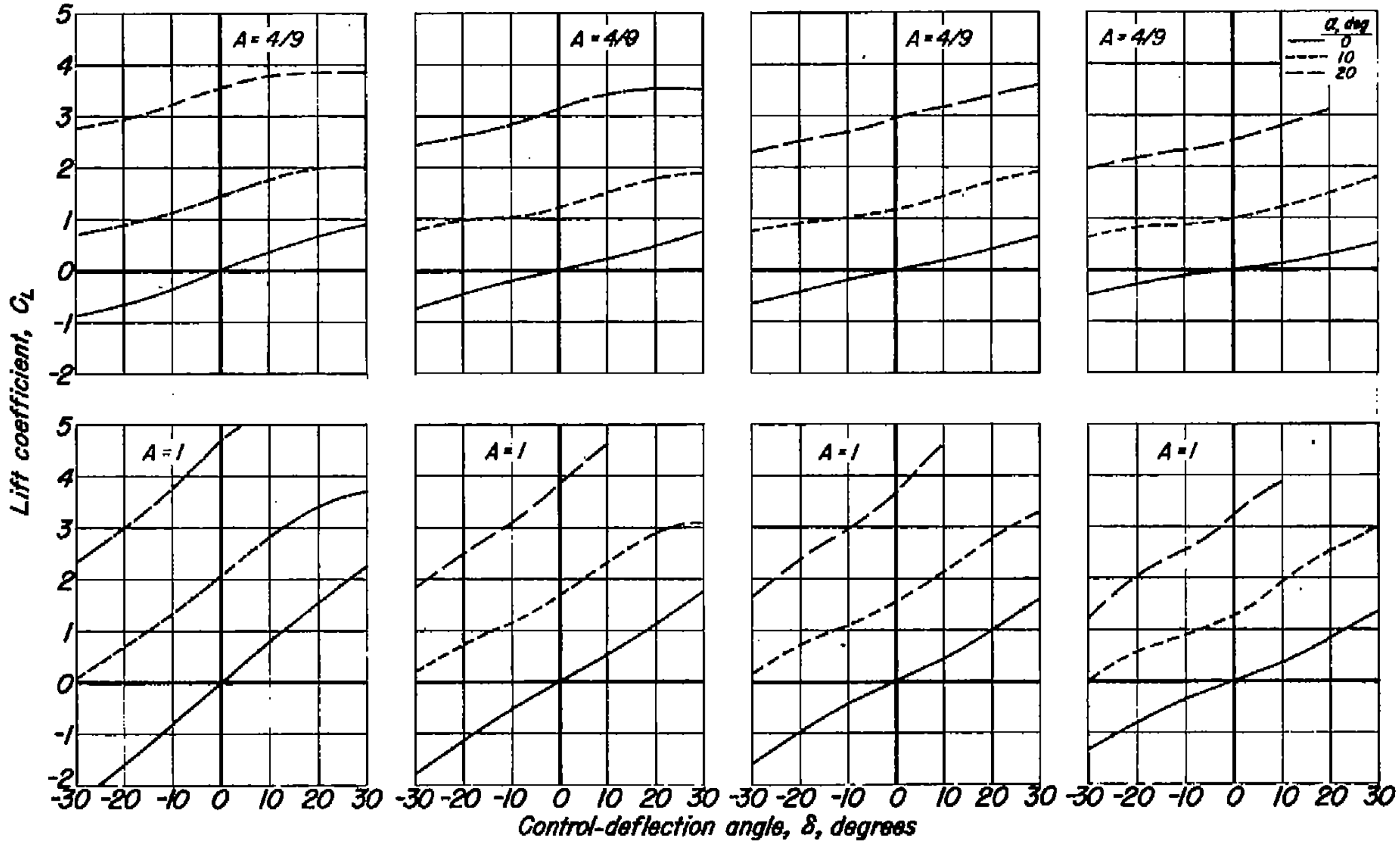
(c) M = 5.05

Figure 2.- Continued.



(d) M = 6.25

Figure 2.- Concluded.



(a) M = 3.00 (b) M = 4.23 (c) M = 5.05 (d) M = 6.25

Figure 3.- Variation of lift coefficient with control-deflection angle for both control-body combinations.

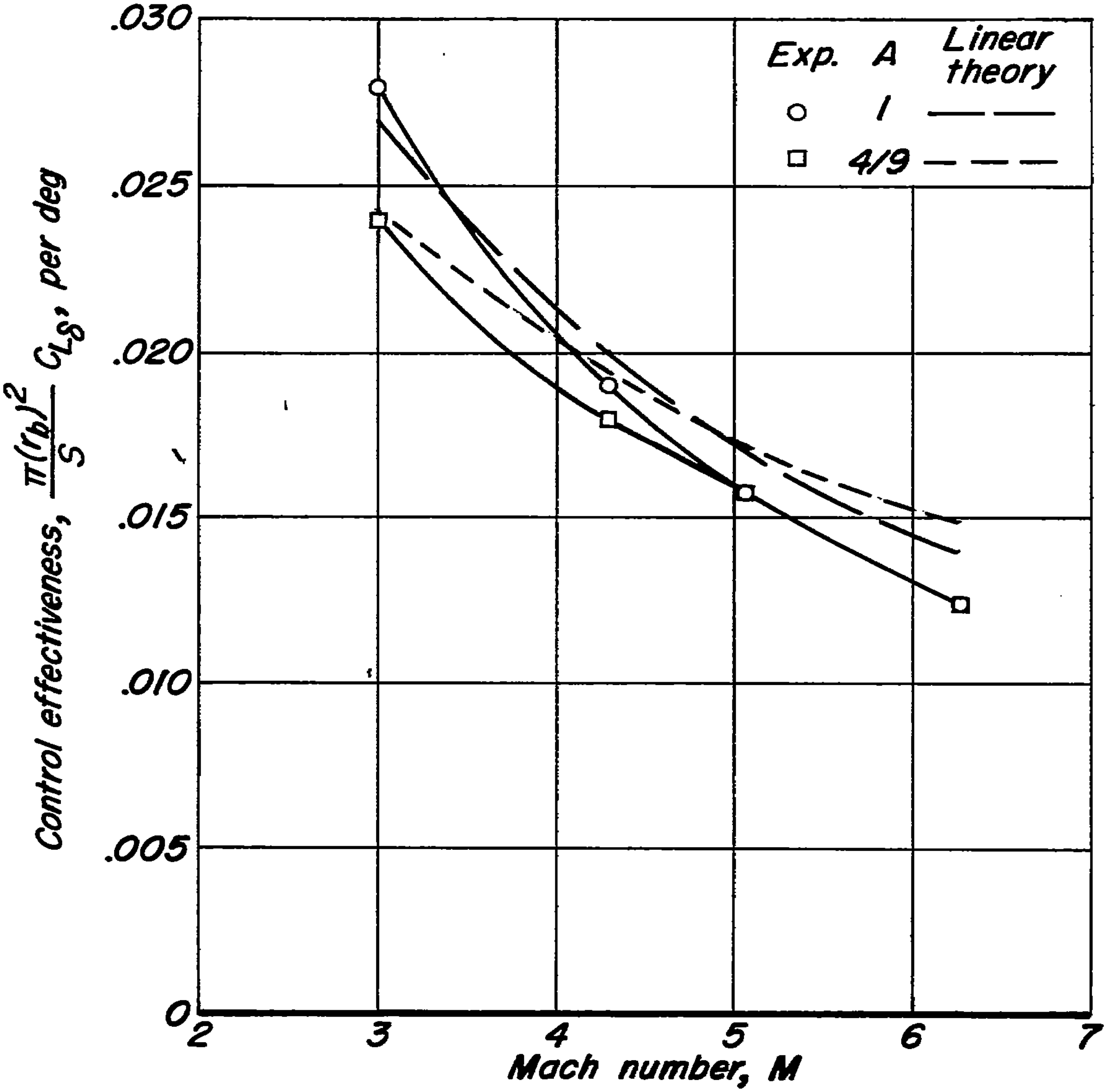


Figure 4.– Variation of control effectiveness with Mach number for both controls tested.

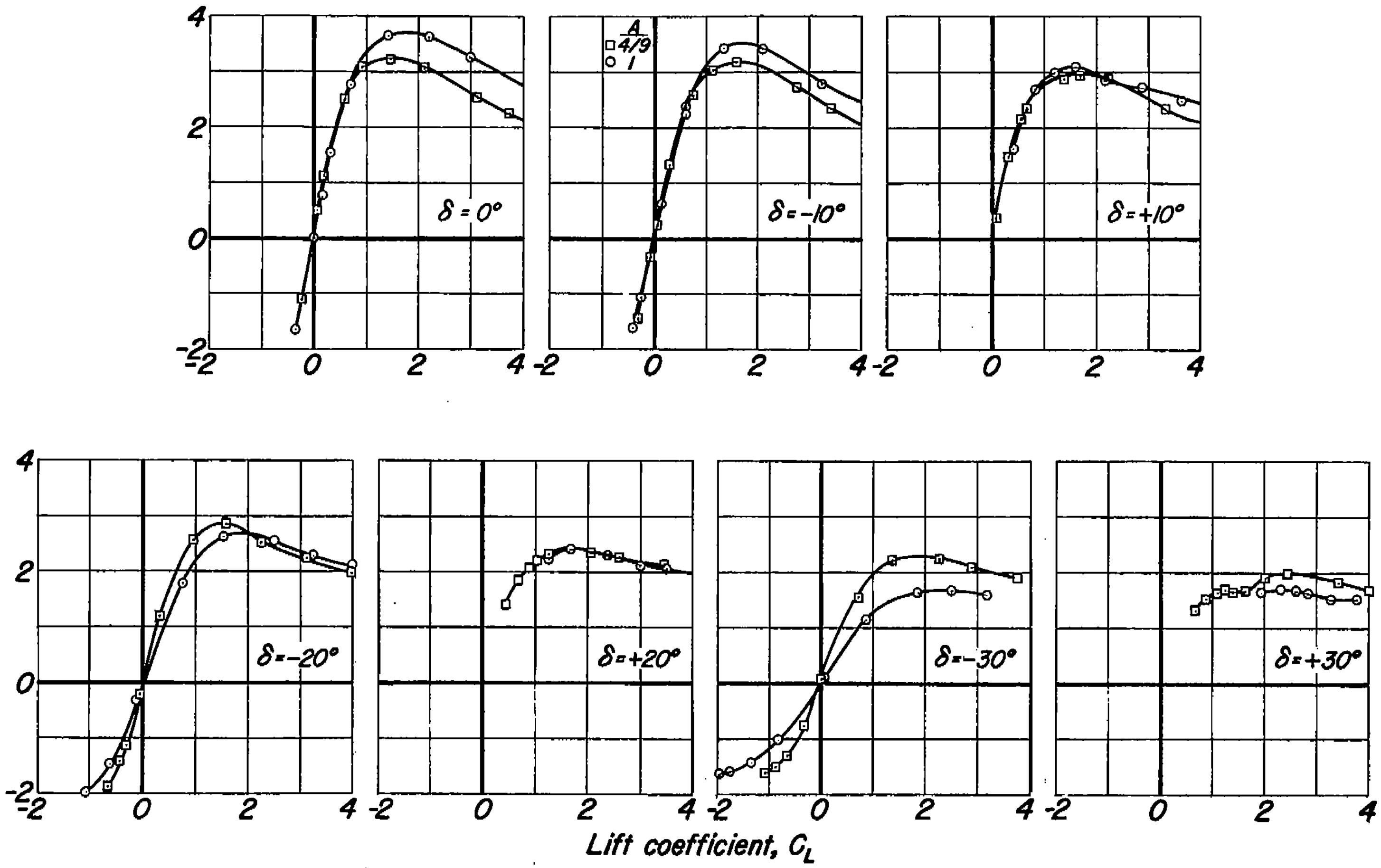


Figure 5.– Variation of lift-drag ratio with lift coefficient for both control-body combinations at M = 3.00.

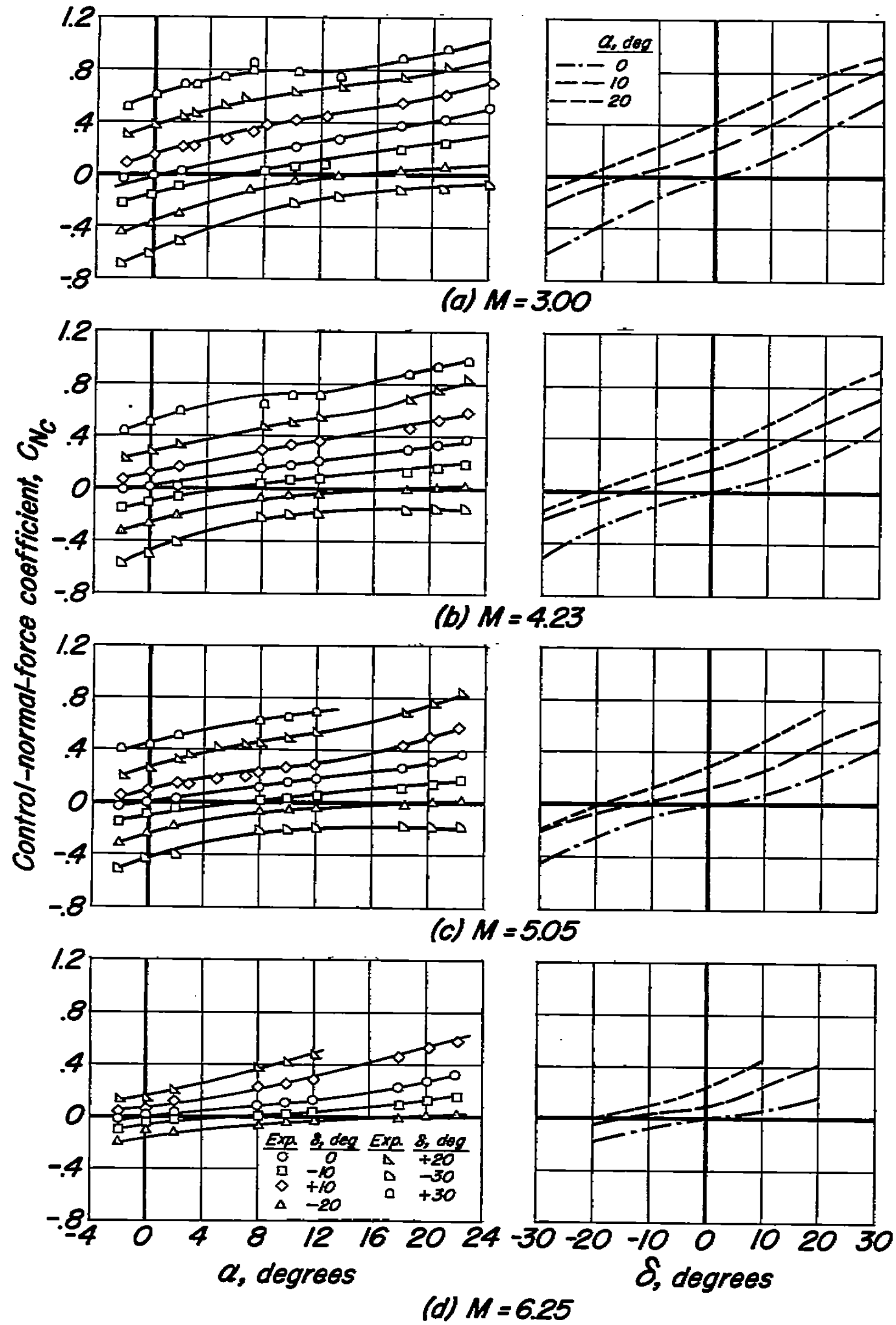


Figure 6.- Variation of control-normal-force coefficient with angle of attack and control deflection for the A = 4/9 control.

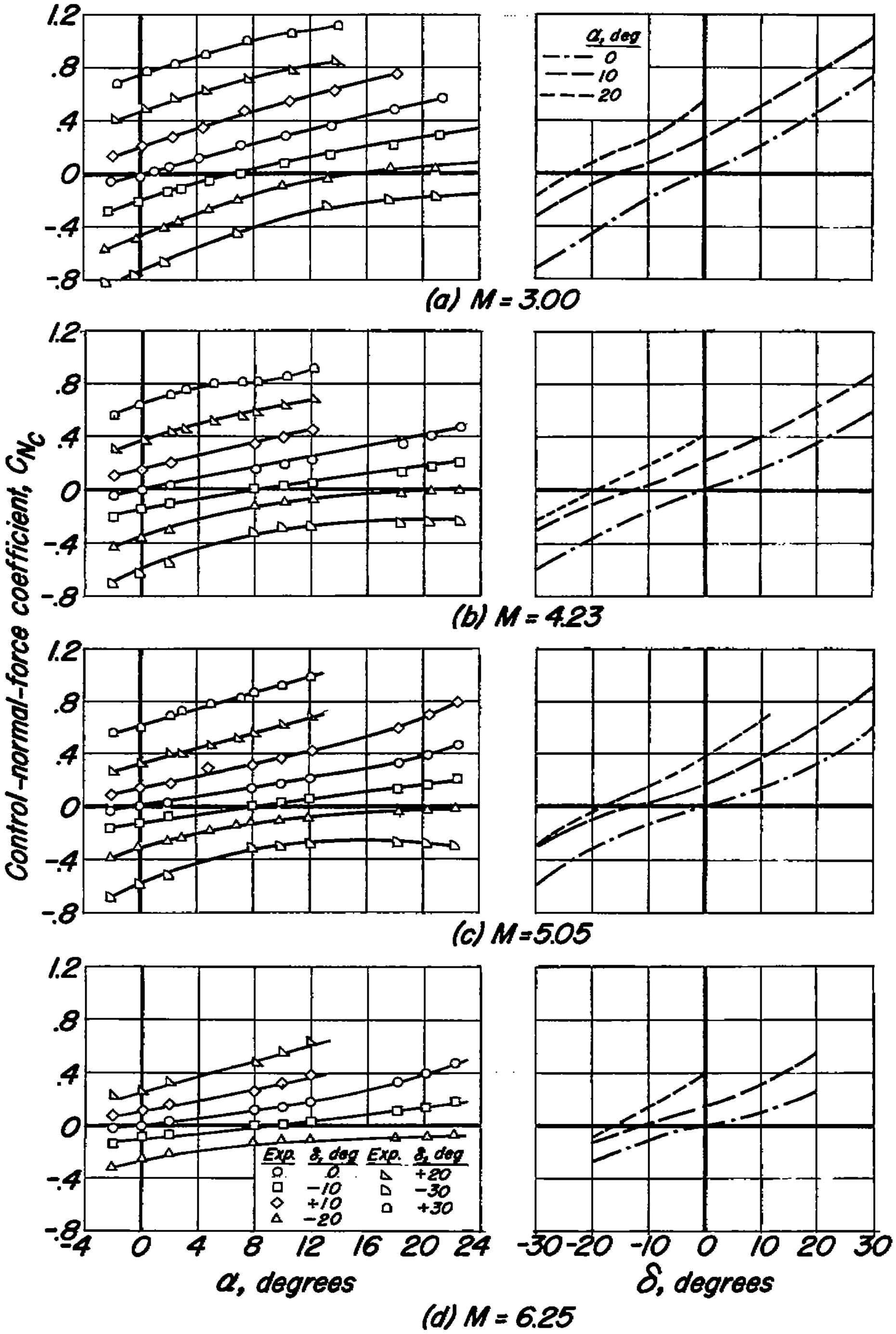


Figure 7.– Variation of control-normal-force coefficient with angle of attack and control deflection for the A = 1 control.

[redacted]

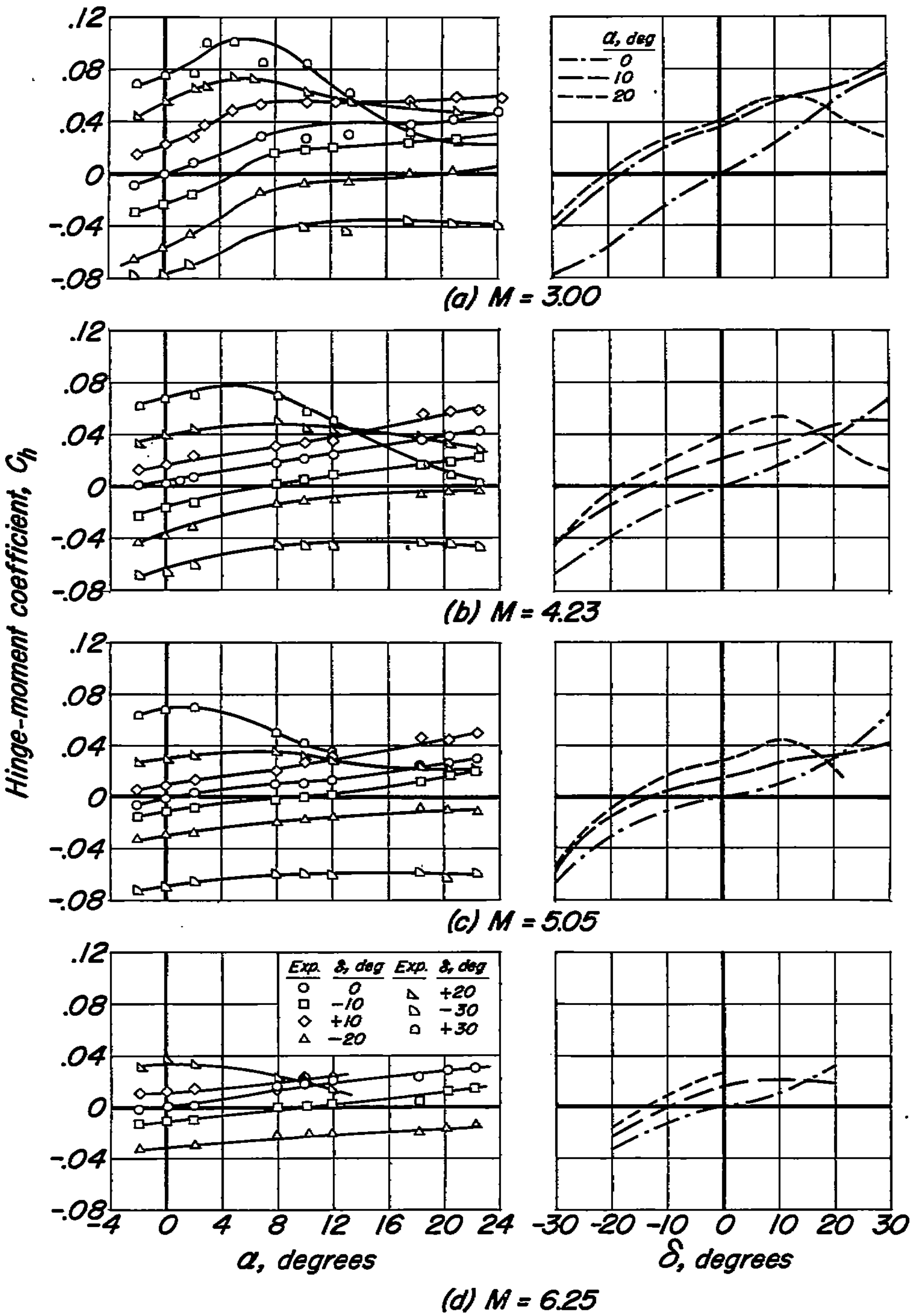


Figure 8.– Variation of hinge-moment coefficient with angle of attack and control deflection for the A = 4/9 control.

[redacted]

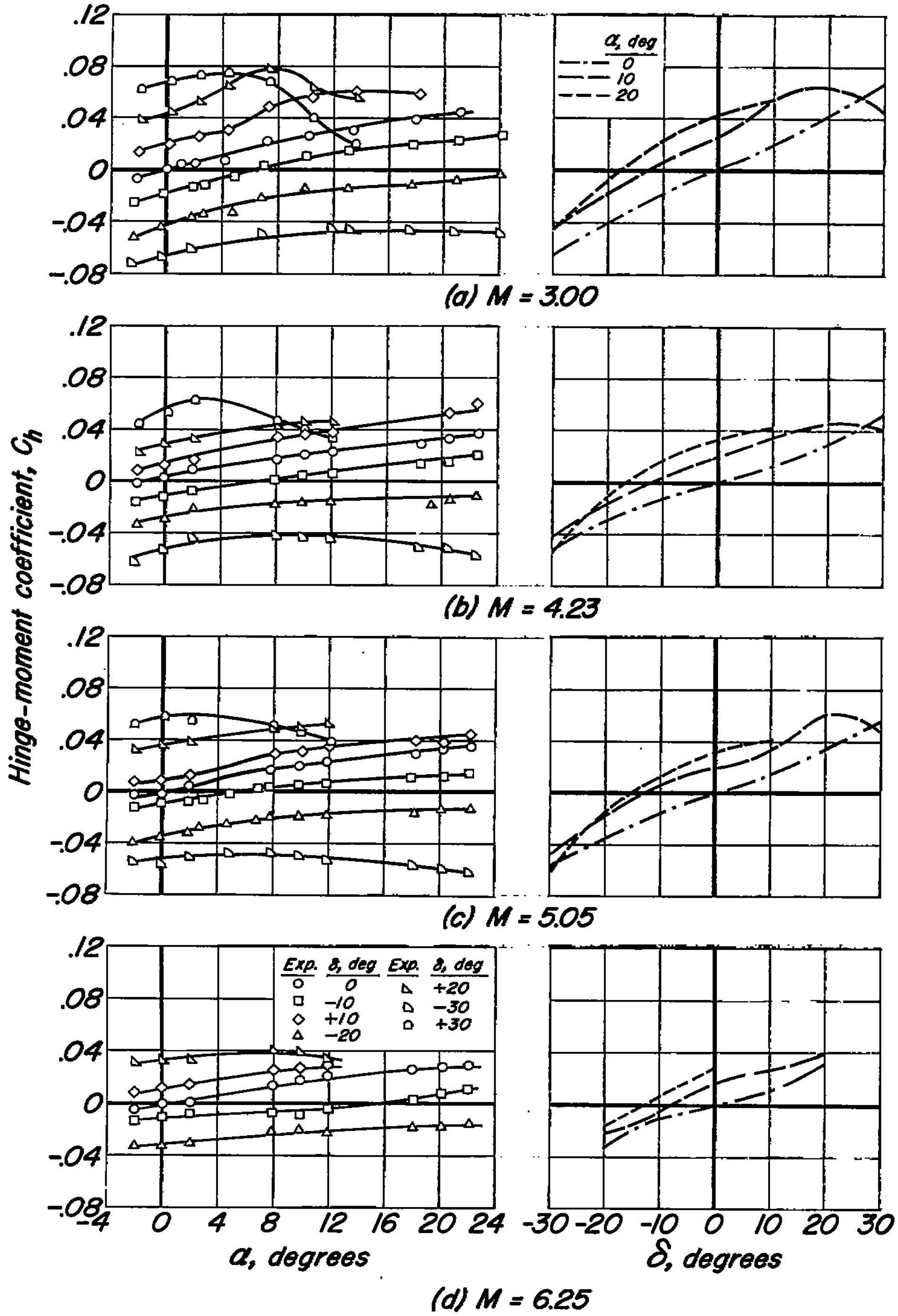
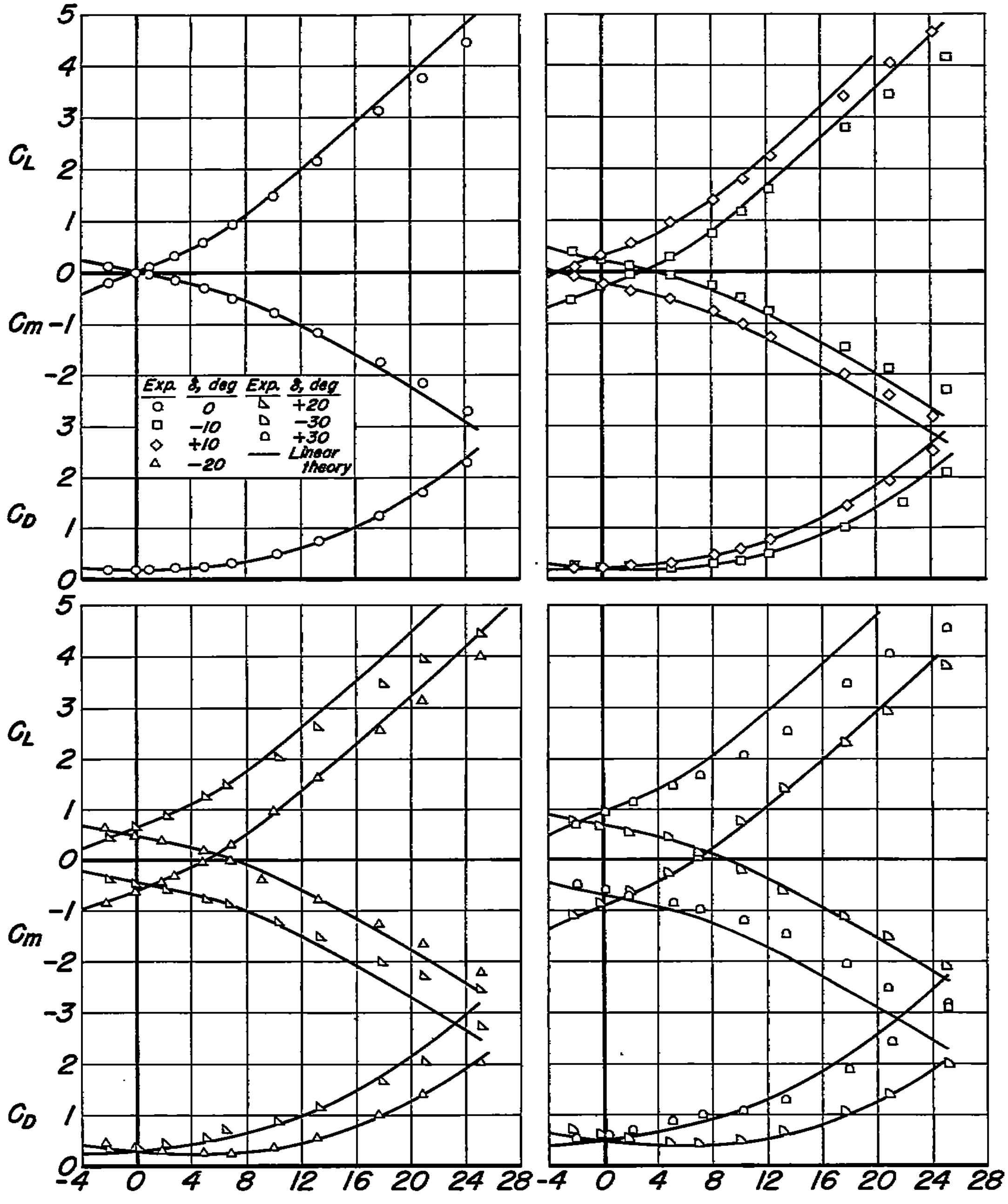


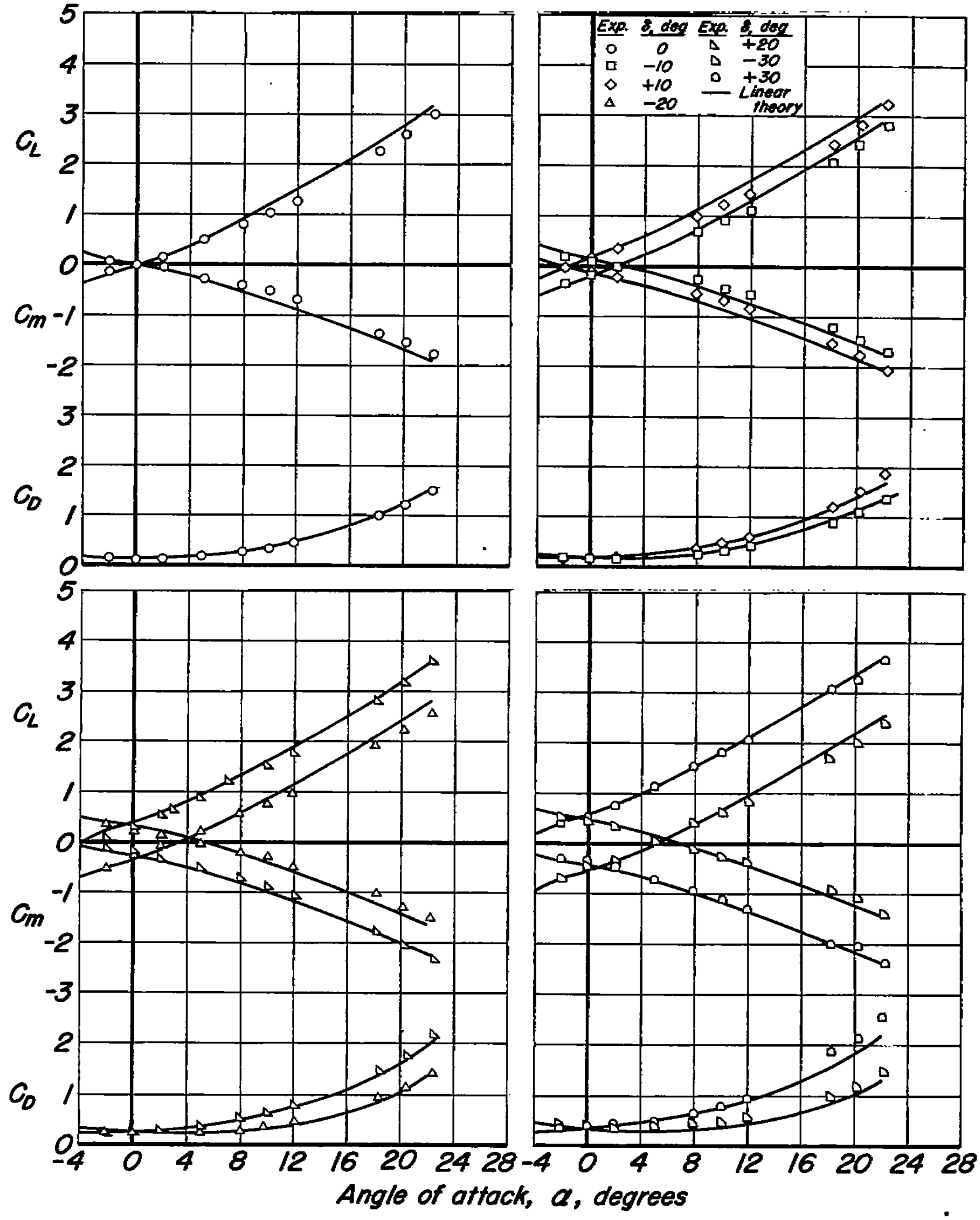
Figure 9.- Variation of hinge-moment coefficient with angle of attack and control deflection for the A = 1 control.



(a) M = 3.00

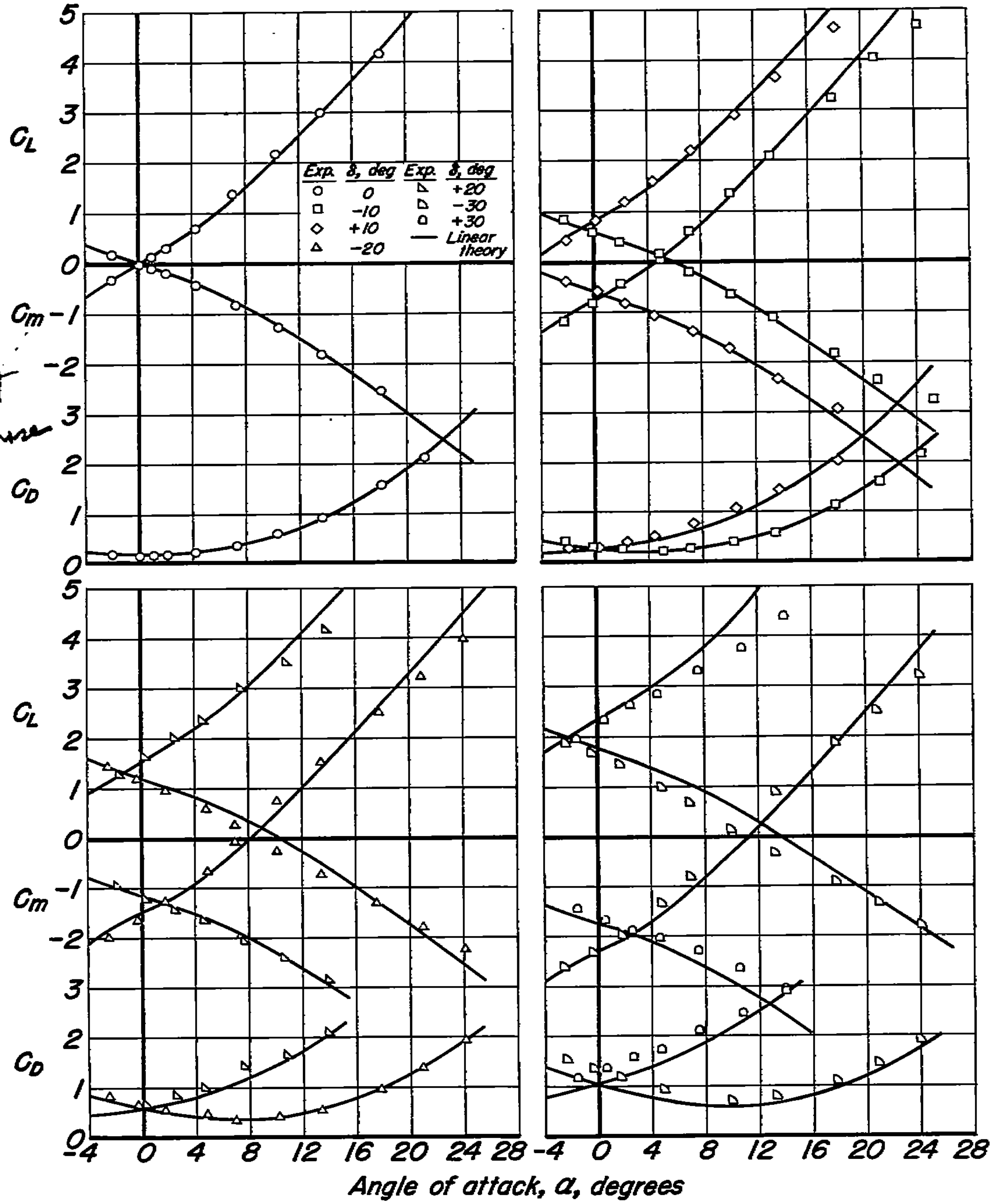
Figure 10.– Comparison of theory and experiment for the aerodynamic characteristics of the A = 4/9 control-body combination.

[redacted]



(b) M = 6.25

Figure 10.- Concluded.

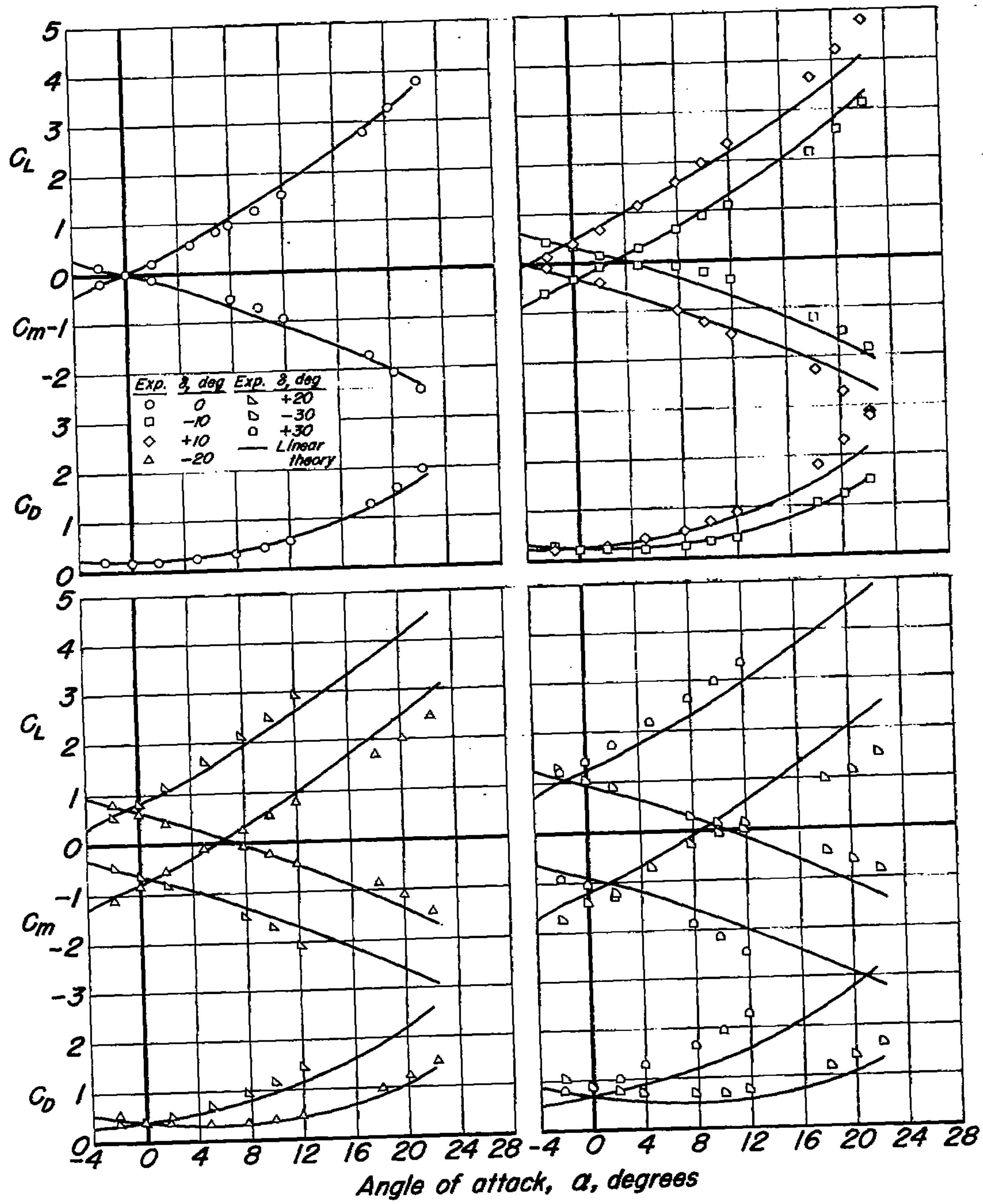


(a) M = 3.00

Figure 11.– Comparison of theory and experiment for the aerodynamic characteristics of the A = 1 control-body combination.

insert body nose

moved to body base area (See p.5)



(b) M = 6.25

Figure 11.- Concluded.

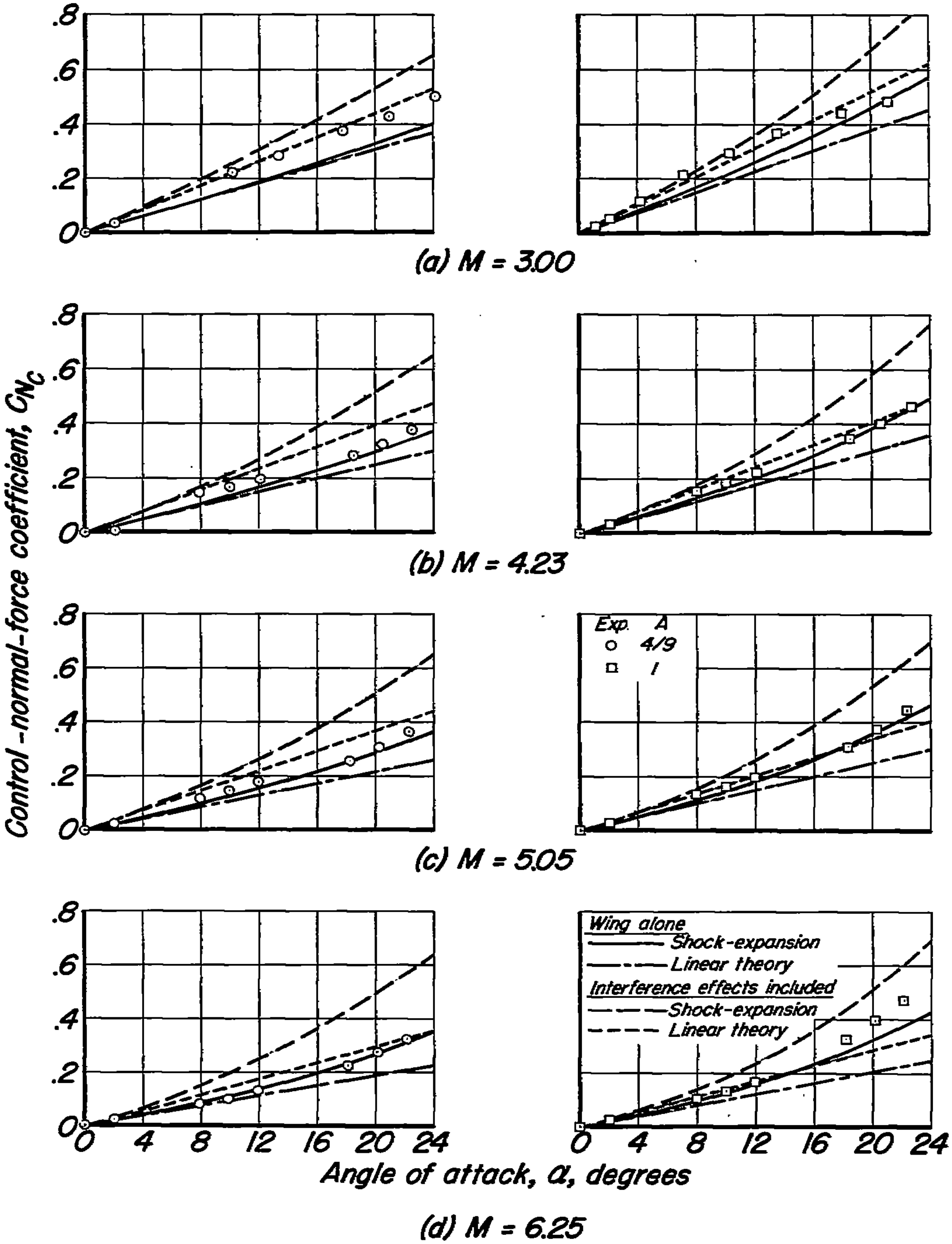


Figure 12.- Variation of control-normal-force coefficient with angle of attack for δ = 0°.

[redacted]

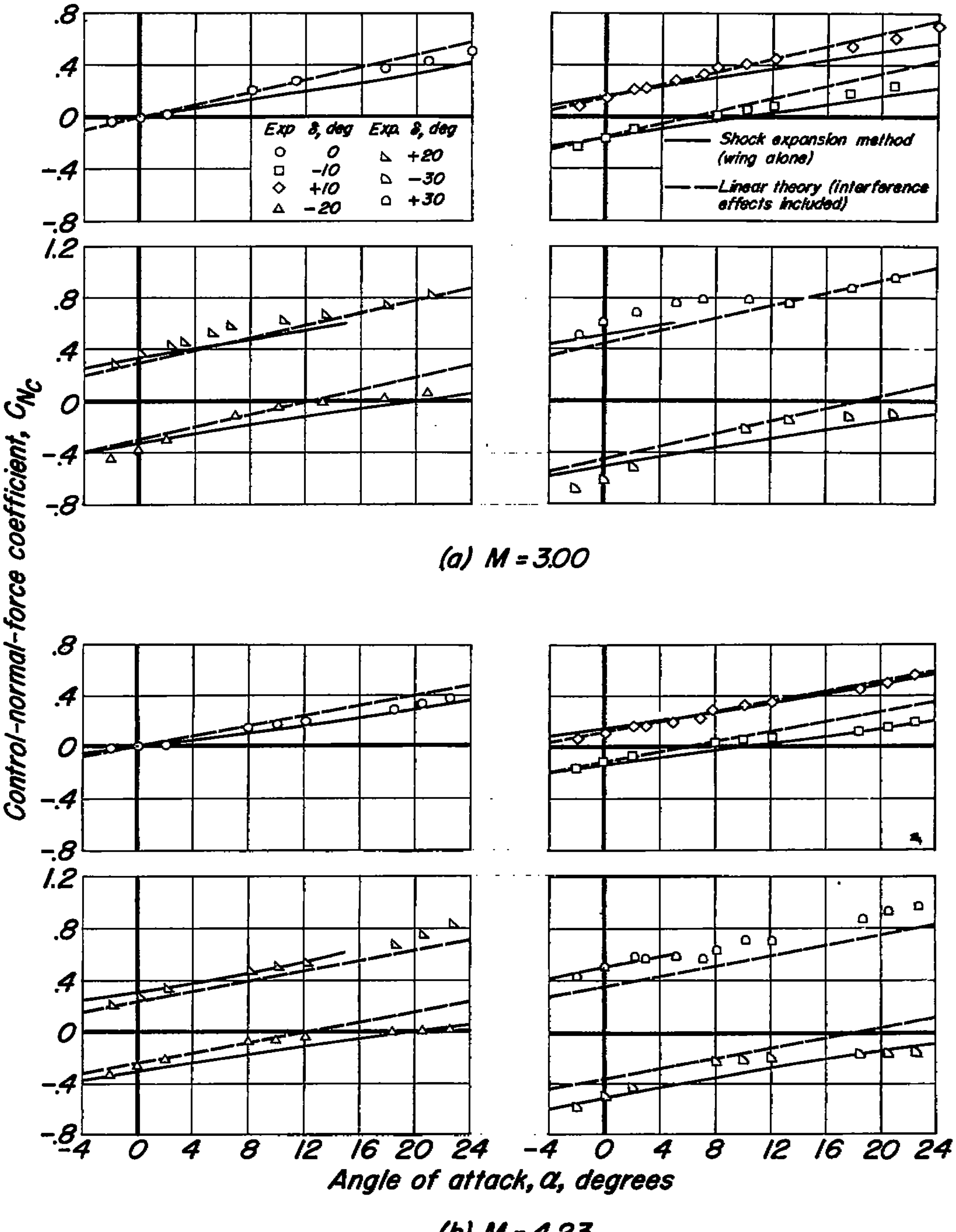
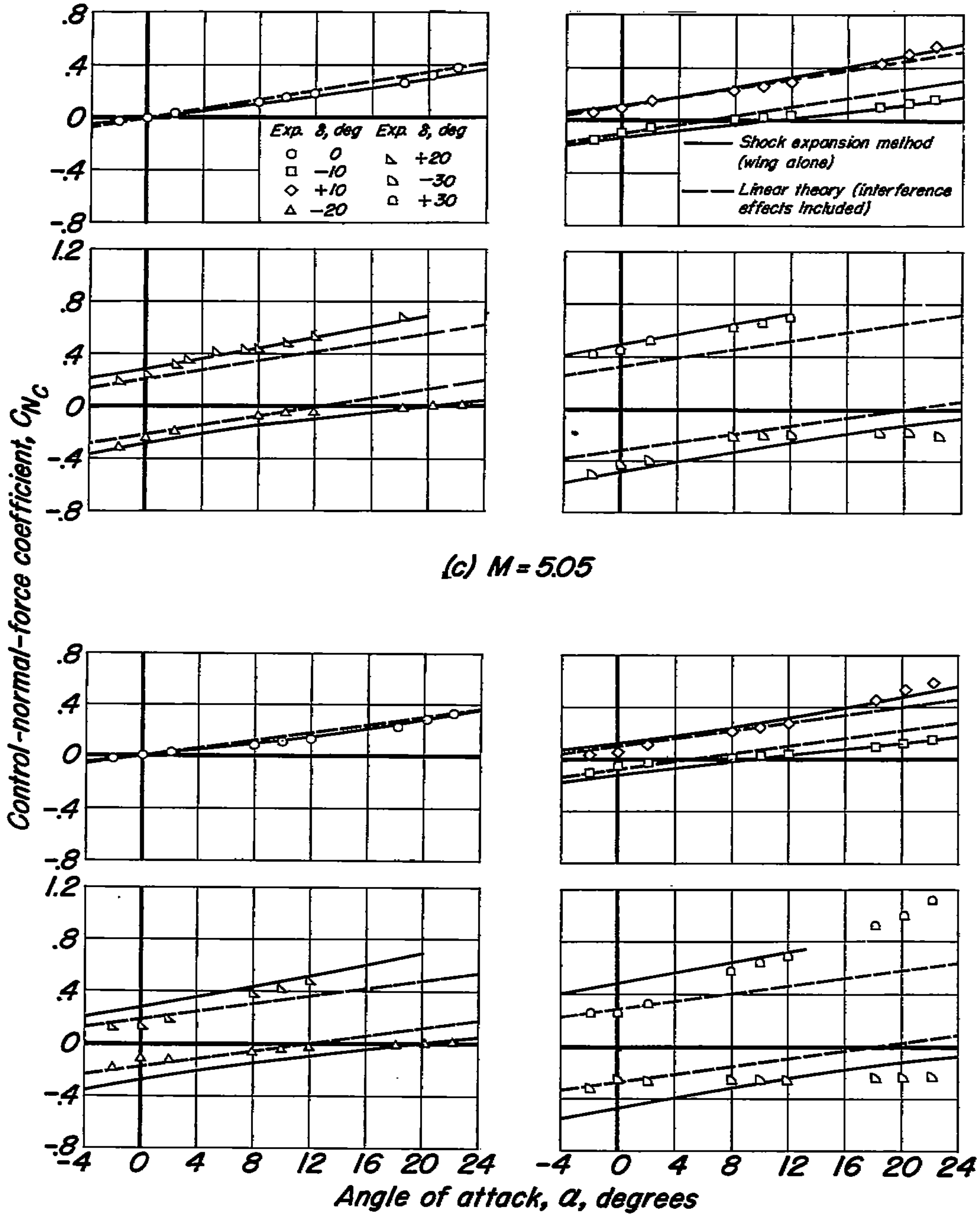


Figure 13.– Variation of control-normal-force coefficient with angle of attack for the A = 4/9 control.



(c) M = 5.05

(d) M = 6.25

Figure 13.- Concluded.

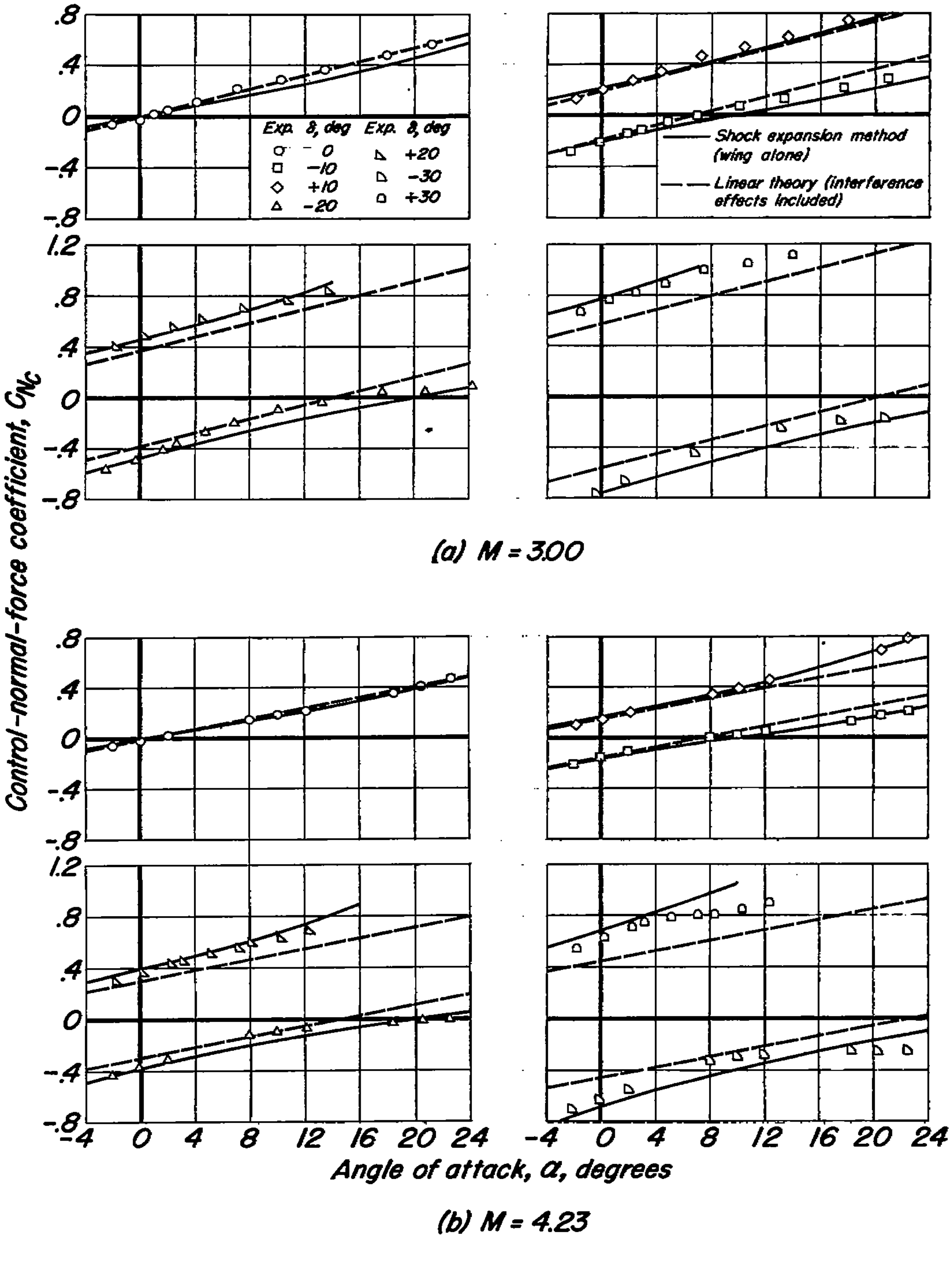
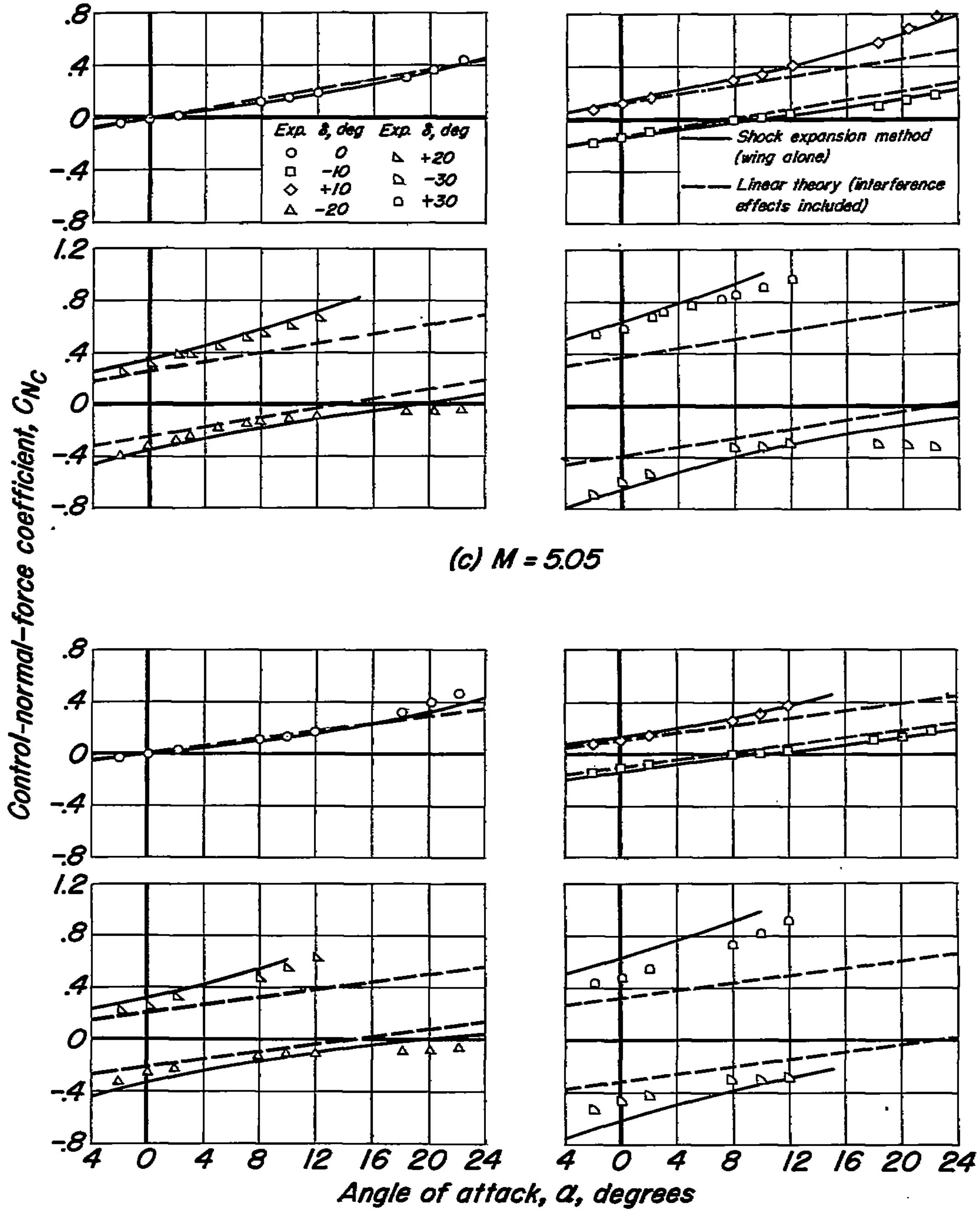


Figure 14.– Variation of control-normal-force coefficient with angle of attack for the A = 1 control.

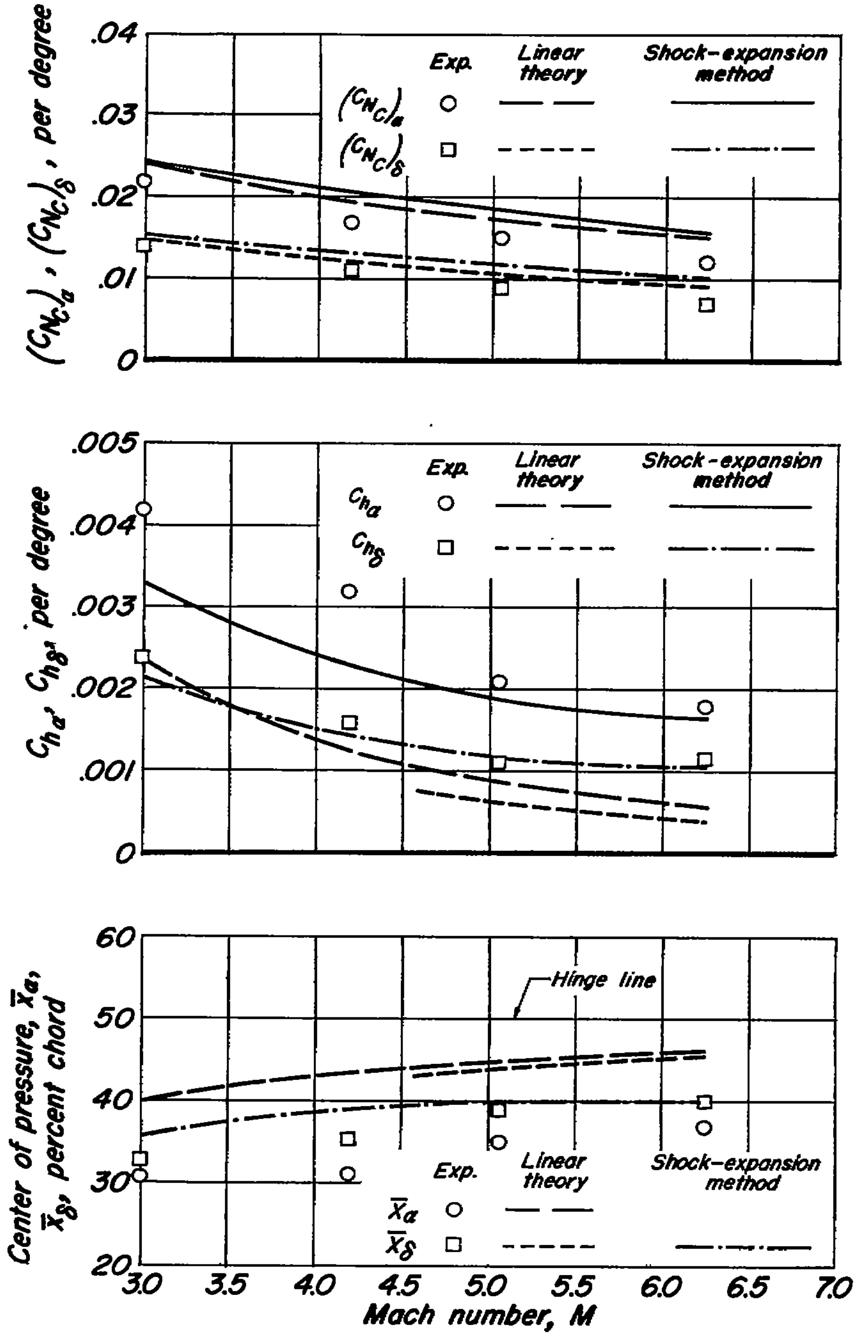
[redacted]



(c) $M = 5.05$

(d) $M = 6.25$

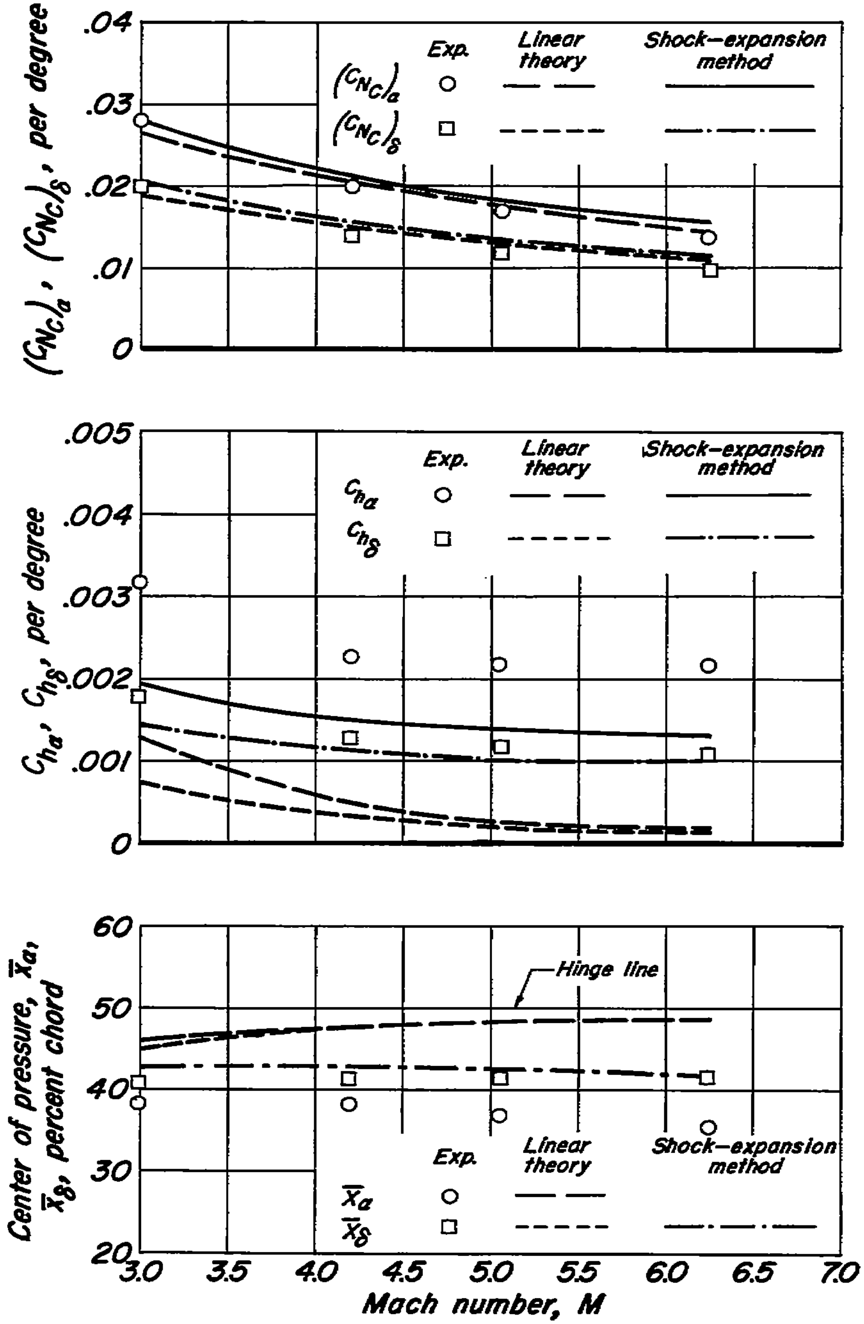
Figure 14.- Concluded.



(a) A = 4/9

Figure 15.– Variation of control surface parameters with Mach number for both controls (at $\alpha = \delta = 0°$).

[redacted]



(b) A = 1

Figure 15.- Concluded.

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